Compressed Air Magazine

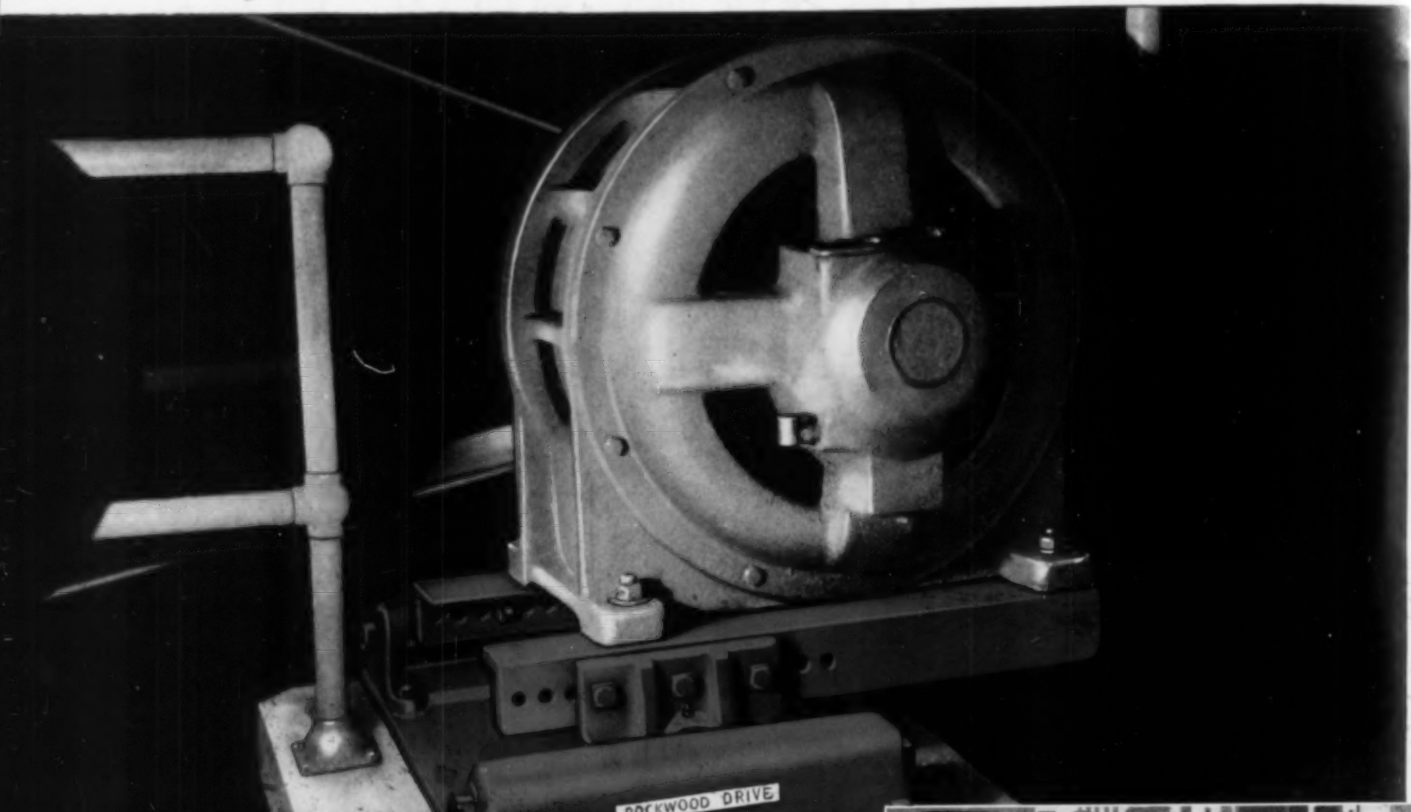
SEPTEMBER 1943

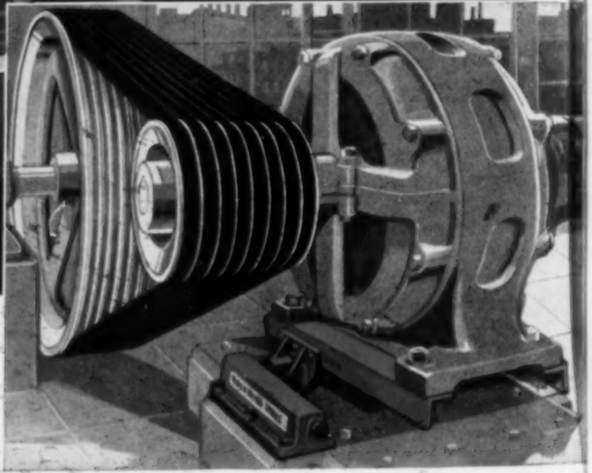
M-4 TANK

They are assembled with impact wrenches and with thousands of other air-operated tools

VOLUME 48 • NUMBER 9 NEW YORK • LONDON

ROCKWOOD *automatic belt tightening* MOTOR BASES





FOR USE WITH FLAT BELTS OR V-BELTS

COMPRESSORS DO BETTER WORK WITH ROCKWOOD SELF TIGHTENING MOTOR BASES.

No wise compressor user today ***will run a belt driven compressor unless the motor is mounted on a Rockwood automatic belt tightening motor base.***

Without the Rockwood motor base both V-belts and flat belts slip at peak loads—with corresponding loss in capacity of compressor ranging up to 10% — 12%. In addition the slippage wears out the belts unduly and wastes power.

With the ***Rockwood motor base*** belt slip is practically eliminated—the compressor is kept up to speed—and belt life is just about doubled. Above all ***compressor performance is made more dependable.***

Many large users of compressors use Rockwood automatic belt tightening motor bases with ***all*** their belted compressors. It will pay you to investigate installing these motor bases on ***your*** belted compressors.

V-belt drives need automatic belt tightening the same as do flat belts—because V-belts, too, stretch under load and then slip. With Rockwood automatic tightening bases the life of V-belts is just about doubled.

ROCKWOOD

INDIANAPOLIS • U.S.A.

Specialists in Power Transmission Equipment Since 1884

Write us or contact your nearby Rockwood Dealer and a Rockwood Engineer will be glad to make recommendations. Prompt deliveries from stock. Your installation should pay for itself the first year.

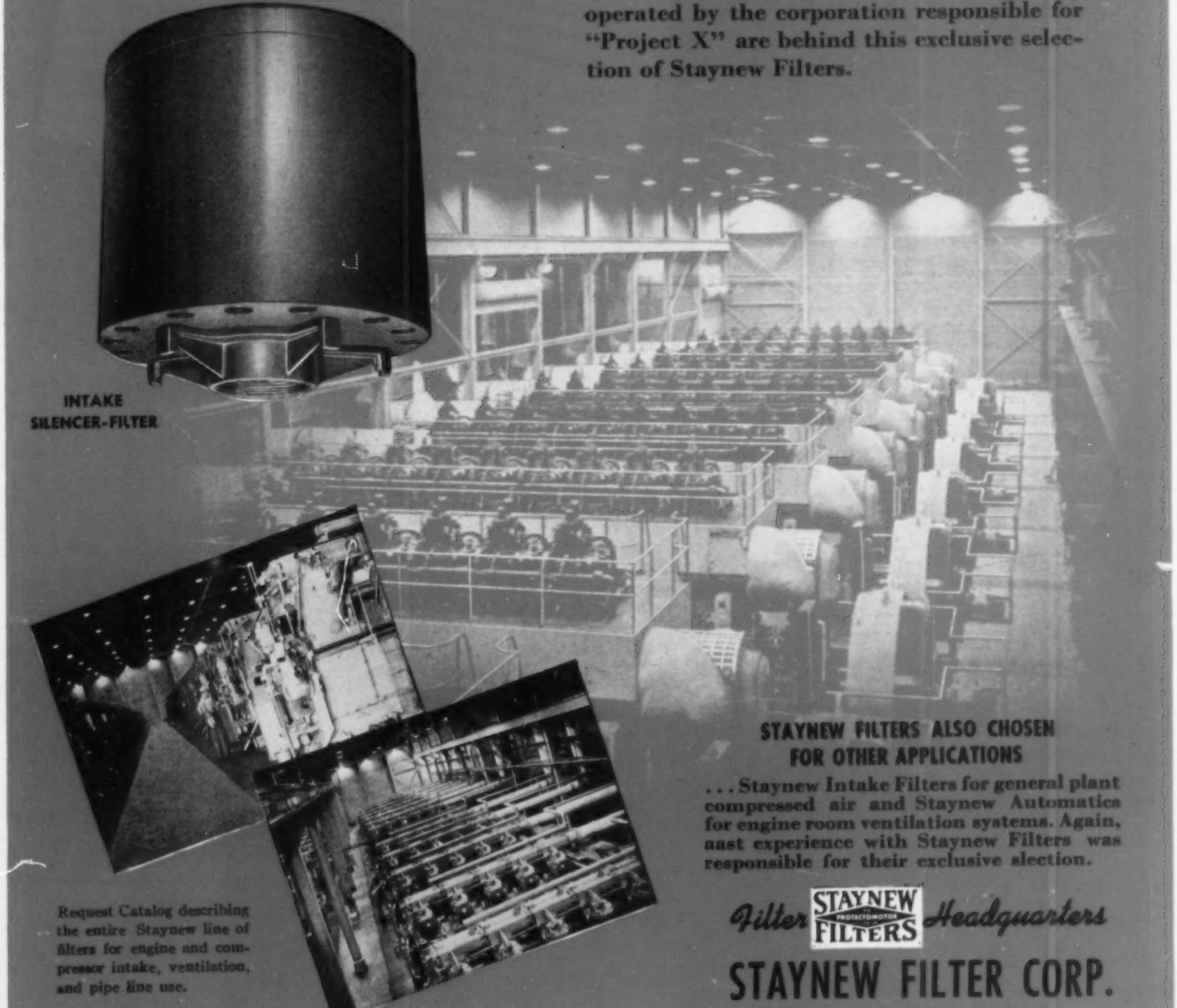
World's Largest Internal Combustion Engine Power Plant is Completely Equipped with

STAYNEW AIR FILTERS

"Project X"—a great new operation vital to America's war effort—uses a total of 123,050 internal combustion engine horsepower. Sixty-eight engines produce this tremendous flow of power—fifty engines requiring 6000 c.f.m. of combustion air each; eighteen requiring 16000 c.f.m. each; total air requirements, 588,000 c.f.m.

Every one of these engines is Staynew Filter-protected—also a world's record, since this is the world's largest intake air filter installation.

Years of satisfactory service in other plants operated by the corporation responsible for "Project X" are behind this exclusive selection of Staynew Filters.



STAYNEW FILTERS ALSO CHOSEN FOR OTHER APPLICATIONS

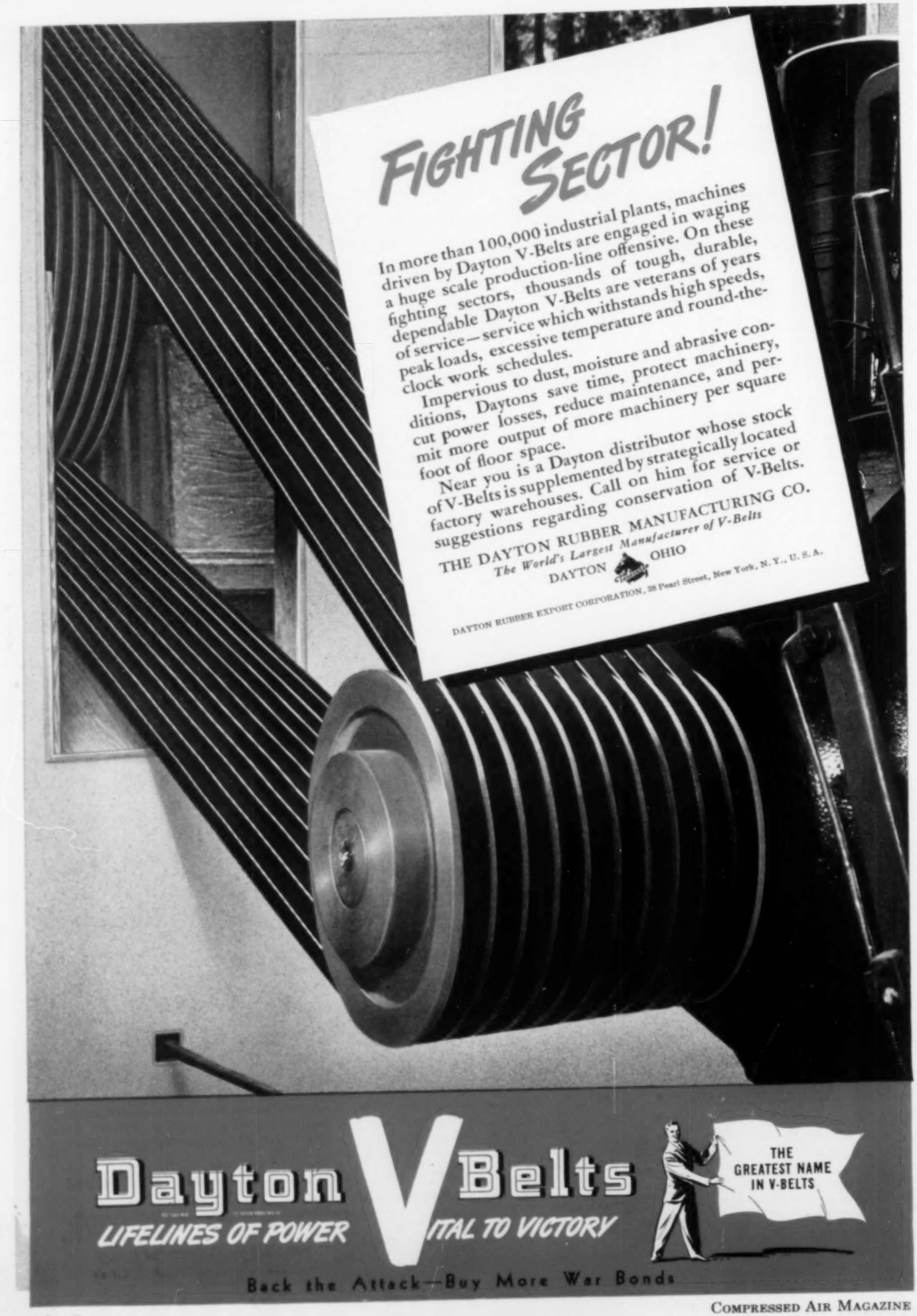
. . . Staynew Intake Filters for general plant compressed air and Staynew Automatics for engine room ventilation systems. Again, aast experience with Staynew Filters was responsible for their exclusive slection.

Request Catalog describing the entire Staynew line of filters for engine and compressor intake, ventilation, and pipe line use.

Filter STAYNEW PROTECTOMOTOR FILTERS *Headquarters*

STAYNEW FILTER CORP.

7 CENTRE PK., ROCHESTER 4, N. Y.
Representatives in Principal Cities


Dayton V Belts
LIFELINES OF POWER VITAL TO VICTORY
THE GREATEST NAME IN V-BELTS
Back the Attack—Buy More War Bonds

FIGHTING SECTOR!

In more than 100,000 industrial plants, machines driven by Dayton V-Belts are engaged in waging a huge scale production-line offensive. On these fighting sectors, thousands of tough, durable, dependable Dayton V-Belts are veterans of years of service—service which withstands high speeds, peak loads, excessive temperature and round-the-clock work schedules.

Impervious to dust, moisture and abrasive conditions, Daytons save time, protect machinery, cut power losses, reduce maintenance, and permit more output of more machinery per square foot of floor space.

Near you is a Dayton distributor whose stock of V-Belts is supplemented by strategically located factory warehouses. Call on him for service or suggestions regarding conservation of V-Belts.

THE DAYTON RUBBER MANUFACTURING CO.
The World's Largest Manufacturer of V-Belts
DAYTON OHIO

DAYTON RUBBER EXPORT CORPORATION, 38 Pearl Street, New York, N.Y., U.S.A.

Each ...THE WORK OF COMPRESSORS!

IN THE tire of this Douglas bomber is compressed air. In the tank of this portable fire-fighting unit is compressed CO_2, both equally important wartime jobs for compressors.

Whether compressing CO_2 for fire-fighting equipment, or compressing air for tire inflation or operation of air-driven mining and other industrial equipment, operators everywhere are maintaining their compressors at peak efficiency . . . lubricated with *Texaco.*

Texaco Alcaid, Algol or Ursa Oils keep compressors free from hard carbon deposits. Valves open wide and shut pressure-tight; rings stay free, ports and air lines clear.

So effective have Texaco lubricants proved in increasing output that they are definitely preferred in many important fields, a few of which are listed in the panel.

A Texaco Lubrication Engineer will gladly cooperate in the selection of the most suitable lubricants for your equipment. Just phone the nearest of more than 2300 Texaco distributing points in the 48 States, or write . . . The Texas Company, 135 E. 42nd St., New York 17, N. Y.

THEY PREFER TEXACO

★ More locomotives and railroad cars in the U. S. are lubricated with Texaco than with any other brand.

★ More revenue airline miles in the U. S. are flown with Texaco than with any other brand.

★ More buses, more bus lines and more bus-miles are lubricated and fueled with Texaco than with any other brand.

★ More stationary Diesel horsepower in the U. S. is lubricated with Texaco than with any other brand.

★ More Diesel horsepower on streamlined trains in the U. S. is lubricated with Texaco than with all other brands combined.

TEXACO REG. T. M.

TEXACO Lubricants

FOR ALL AIR COMPRESSORS AND TOOLS

TUNE IN THE TEXACO STAR THEATRE EVERY SUNDAY NIGHT—CBS ★ HELP WIN THE WAR BY RETURNING EMPTY DRUMS PROMPTLY

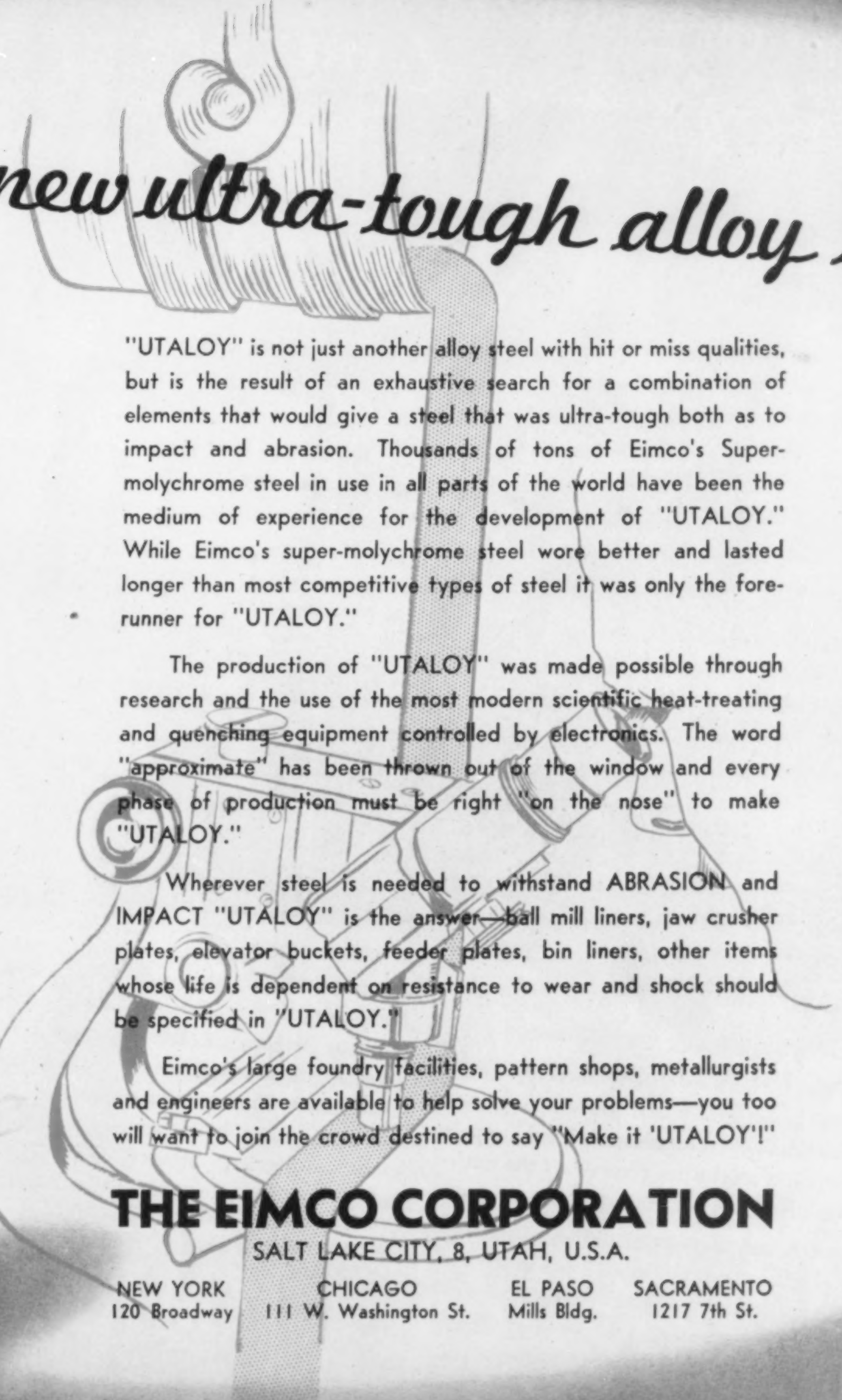
Announcing

Eimco's

ALLOY
UTALOY
STEEL

RESEARCH AND PRECISION CONTROLS WITH MORE THAN A QUARTER CENTURY OF ELECTRIC FURNACE STEEL-CASTING EXPERIENCE COMBINED TO MAKE—

UTALOY



new ultra-tough alloy steel

"UTALOY" is not just another alloy steel with hit or miss qualities, but is the result of an exhaustive search for a combination of elements that would give a steel that was ultra-tough both as to impact and abrasion. Thousands of tons of Eimco's Super-molychrome steel in use in all parts of the world have been the medium of experience for the development of "UTALOY." While Eimco's super-molychrome steel wore better and lasted longer than most competitive types of steel it was only the forerunner for "UTALOY."

The production of "UTALOY" was made possible through research and the use of the most modern scientific heat-treating and quenching equipment controlled by electronics. The word "approximate" has been thrown out of the window and every phase of production must be right "on the nose" to make "UTALOY."

Wherever steel is needed to withstand ABRASION and IMPACT "UTALOY" is the answer—ball mill liners, jaw crusher plates, elevator buckets, feeder plates, bin liners, other items whose life is dependent on resistance to wear and shock should be specified in "UTALOY."

Eimco's large foundry facilities, pattern shops, metallurgists and engineers are available to help solve your problems—you too will want to join the crowd destined to say "Make it 'UTALOY'!"

THE EIMCO CORPORATION
SALT LAKE CITY, 8, UTAH, U.S.A.

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120 Broadway

CHICAGO
111 W. Washington St.

EL PASO
Mills Bldg.

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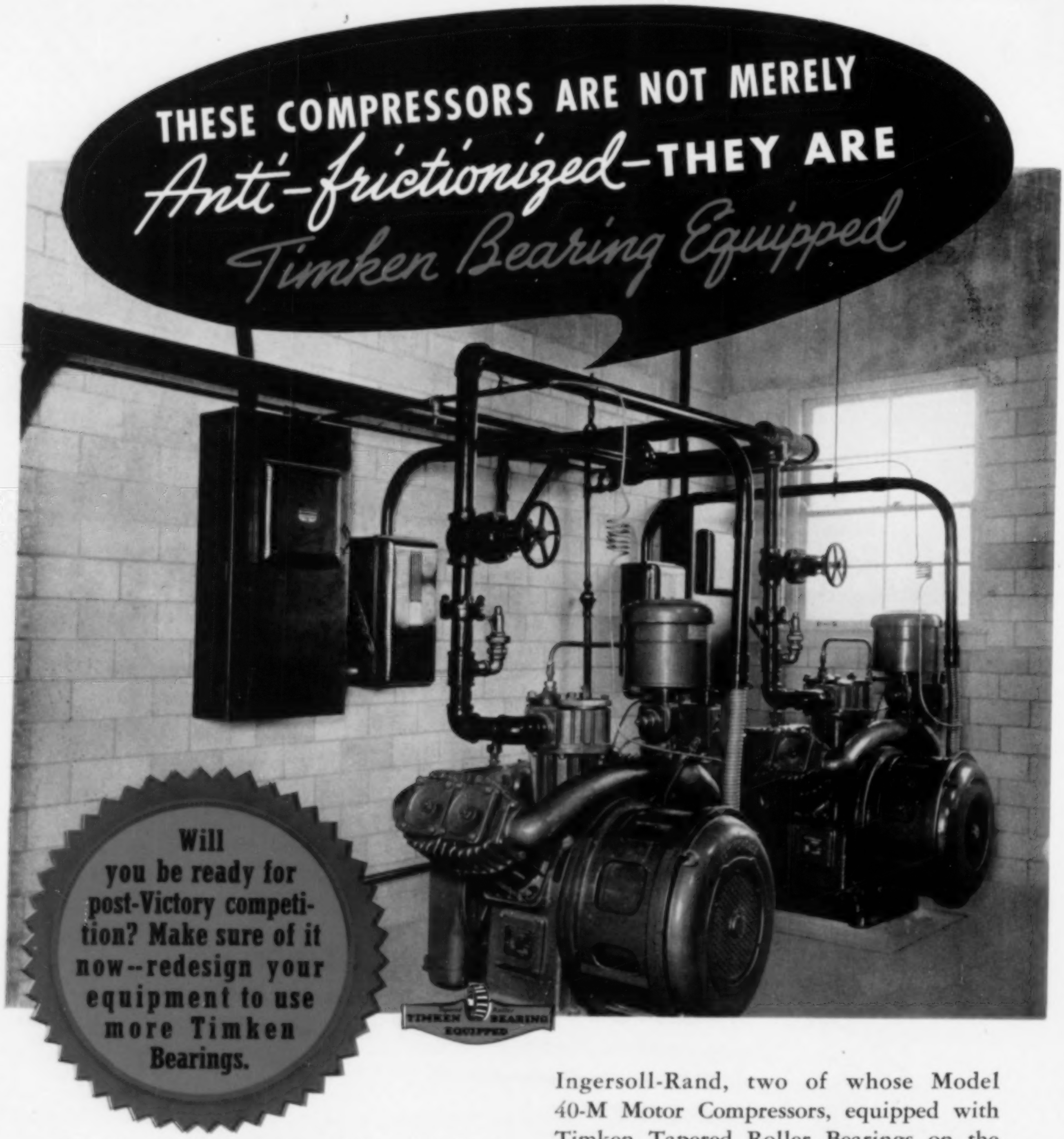
1217 7th St.


THESE COMPRESSORS ARE NOT MERELY
Anti-frictionized—THEY ARE
Timken Bearing Equipped
Will you be ready for post-Victory competition? Make sure of it now--redesign your equipment to use more Timken Bearings.
TIMKEN BEARING EQUIPPED

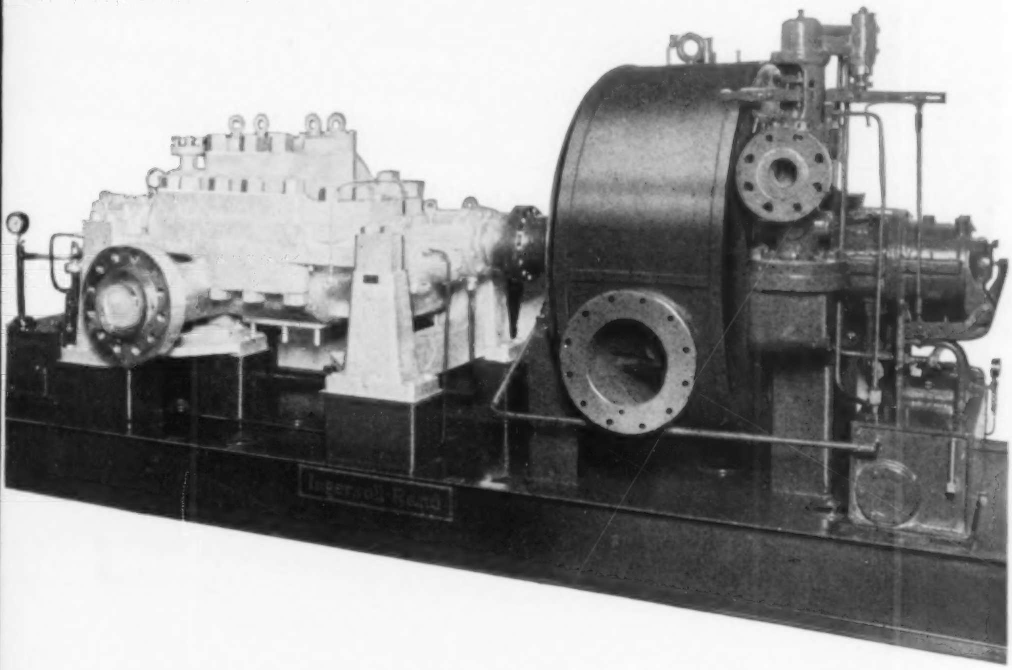
It isn't sufficient to specify merely "anti-friction bearings" when purchasing an anti-frictionized compressor of any type; for then you might not receive *all* the anti-friction advantages to which you are entitled.

The surest way to get them all is to specify "Timken Bearing Equipped"—that means smooth operation; power economy; protection against radial, thrust and combined loads; permanent alignment of moving parts; low maintenance expense.

Ingersoll-Rand, two of whose Model 40-M Motor Compressors, equipped with Timken Tapered Roller Bearings on the crank shaft, are shown in the photograph, have used Timken Bearings for years; know they can be depended on for efficient, enduring service. The Timken Roller Bearing Company, Canton, Ohio.

TIMKEN
TRADE-MARK REG. U. S. PAT. OFF.
TAPERED ROLLER BEARINGS

TERRY



THE ROTOR OF THIS BOILER FEED TURBINE IS DOUBLE RIM PROTECTED!

The 1250 H. P. Turbine shown above employs the Terry Solid Wheel Rotor. The wheel is made from a single steel forging and the buckets are milled directly in the wheel.

The buckets are protected by rims at the sides of the wheel. These rims would take without damage any rubbing that might occur if the clearance became reduced.

With this construction it is impossible for the blades to foul and frequent inspections of the thrust bearing are not required to obtain safe and dependable operation.

The Terry Wheel Turbine is fully described in our Bulletin S-116.

T-1152

THE TERRY STEAM TURBINE COMPANY
TERRY SQUARE, HARTFORD, CONN.

These Ⓛ Physical Properties Save Critical Alloys

SPECIFIED MINIMUM PHYSICAL PROPERTIES OF LEBANON Ⓛ EMERGENCY CAST STEELS

CARBON STEELS

Lebanon Designation	Nominal Analysis						Specified Minimum Physical Properties				
	C	Si	Mn	Ni	Cr	Mo	Tensile Strength	Yield Point	Elong. in 2"	Red. Area	B. H. (Avg.)
Ⓛ B	.25	.40	.65				65,000	35,000	24.0	35.0	135
Ⓛ A	.40	.40	.75	†	†	†	80,000	43,000	17.0	25.0	175
Ⓛ C	.40	.40	.75	†	†	†	100,000	75,000	15.0	30.0	200
Ⓛ D	.40	.40	.75	†	†	†	125,000	85,000	10.0	20.0	250

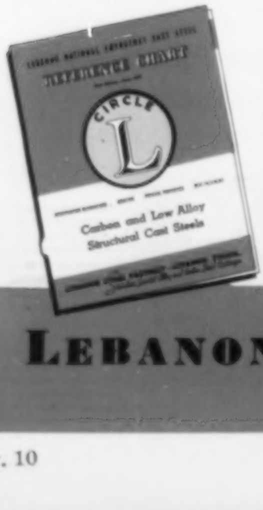
*NE ALLOY STEELS

Lebanon Designation	C	Si	Mn	Ni	Cr	Mo	Tensile Strength	Yield Point	Elong. in 2"	Red. Area	B. H. (Avg.)
Ⓛ 205 (A)	.30	.40	.80	.60	.60	.20	85,000	53,000	22.0	35.0	185
Ⓛ 205 (B)	.30	.40	.80	.60	.60	.20	105,000	85,000	15.0	30.0	220
Ⓛ 205 (C)	.30	.40	.80	.60	.60	.20	120,000	100,000	12.0	25.0	260
Ⓛ 205 (D)	.30	.40	.80	.60	.60	.20	150,000	125,000	10.0	20.0	320

† Residual alloys contained.
* Supplied with approval of W.P.B.
NOTE: Standard grades of Ⓛ alloy steel castings available with proper priority and W.P.B. approval.

Complete Data at a Glance!

A single spread of this file-size reference chart gives you the essential data about Circle Ⓛ Emergency Cast Steels—both Carbon and NE Alloys. Designations... nominal analysis... specified minimum physical properties . . . and heat treatment... all lie before you without the need to flip a page! The complete chart is available to executives, engineers and metallurgists. Write now.



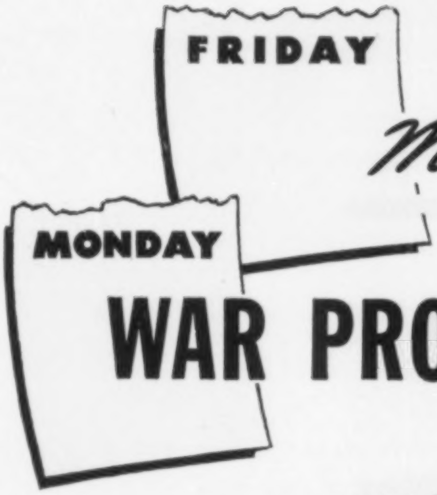
In spite of close restrictions on the use of critical alloys, Lebanon Circle Ⓛ Emergency Cast Steels provide physical properties that meet specifications for important war production. These steels combine strength . . . hardness . . . and toughness to the degrees demanded by their different functions. They measure up to customer requirements in a manner not expected of emergency materials.

Consultation with Lebanon foundry engineers and metallurgists simplifies selection of the correct Lebanon Circle Ⓛ Emergency Cast Steel. These technicians consider all factors . . . including application, design, thickness, hardness and shock resistance. Their consultation services are available upon request.

LEBANON STEEL FOUNDRY LEBANON, PENNA.

ORIGINAL AMERICAN LICENSEE GEORGE FISCHER (SWISS CHAMOTTE) METHOD

LEBANON *Stainless and Special Alloy* STEEL CASTINGS



motor failure

WAR PRODUCTION AS USUAL

125 HP FOUNDRY MOTOR FAILED FRIDAY, 4 AM. EMERGENCY CALL TO NEAREST WESTINGHOUSE MANUFACTURING & REPAIR PLANT STARTED WORK IMMEDIATELY. NEW COILS FORMED, INSULATED, TREATED, STATOR STRIPPED, REWOUND, DIPPED, BAKED, TESTED. DELIVERED MONDAY, 2 PM, TO WAR PLANT. BAD NEWS FOR AMERICA'S ENEMIES.

Westinghouse
MANUFACTURING AND REPAIR

J-90453

***IF* THE EQUIPMENT NEEDING MAINTENANCE OR REPAIR IS VITAL TO THE WAR EFFORT ...PHONE OR WIRE THE NEAREST WESTINGHOUSE "M & R" PLANT FOR**

Westinghouse
Manufacturing & Repair

EMERGENCY SERVICE

33 PLANTS • • • ONE NEAR YOU!

Accidents Are Axis Aids

SAFETY FIRST

Carelessness on the job, resulting in accident and lost time, helps the enemy. An injured worker is useless to himself, to his employer and to his country.

Never exceed manufacturer's stability ratings in operating a crane. Do not raise crane boom too close to vertical, as a sudden release of load may throw it back over cab. Be sure footing is secure, especially when handling limit loads or when working with a high boom-angle.

While excavator is being propelled, make sure the revolving frame is locked into position.

Block treads against movement before shifting jaw steering clutches on a steep incline.

When converting to shovel, remove any extra crane counterweight.

Load trucks over the rear end; avoid swinging dipper or bucket over the truck cab.

Keep machine clean. Grease and oil on floor become slippery traps and may lead to dangerous falls.

Don't allow doors to swing; keep them securely latched.

Be sure that fire extinguisher is always handy and in good condition. Know how to use it instantly.

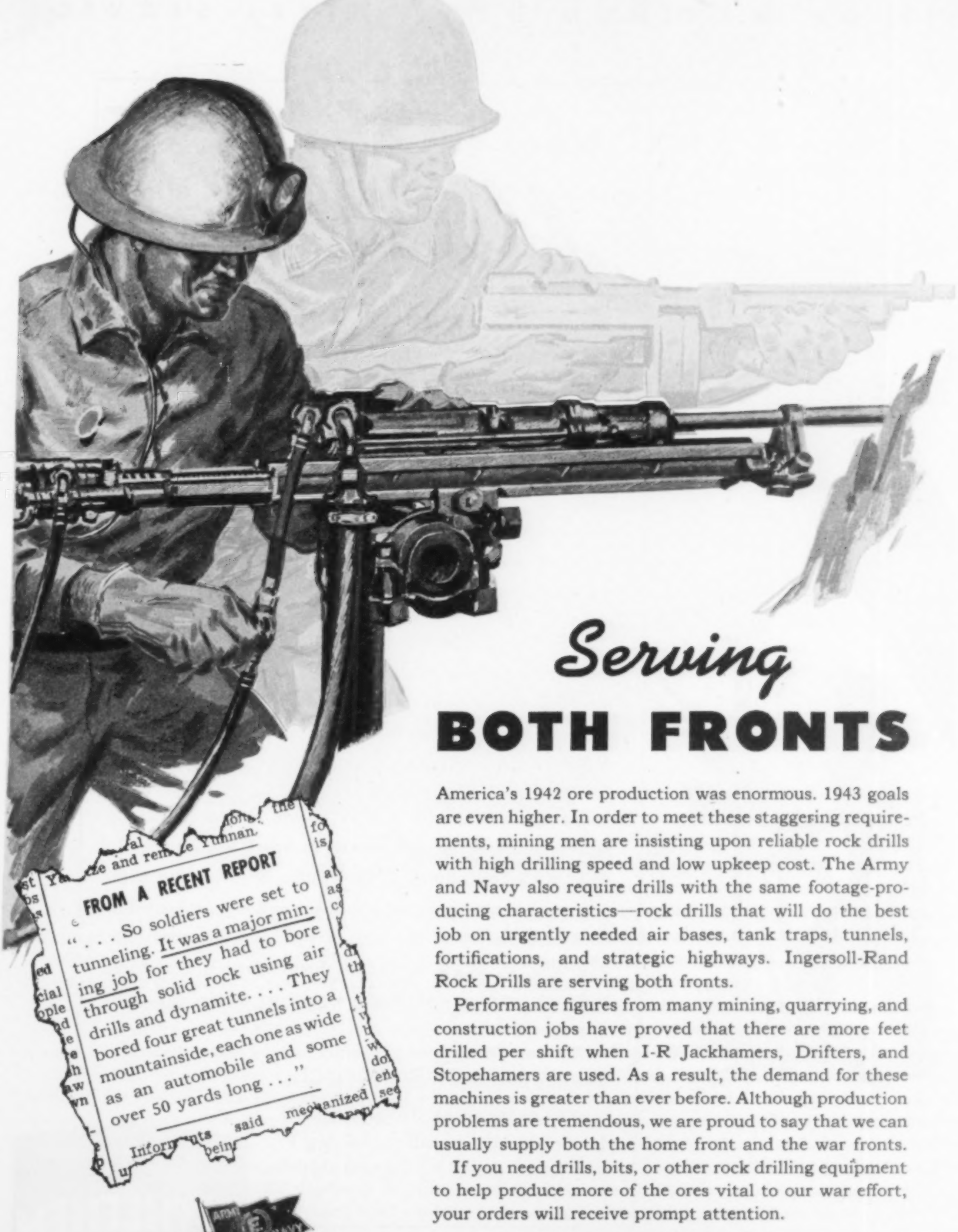
Remain alert and safety-conscious at all times. Don't take unnecessary risks. Watch out for the other fellow.

Safe care of your machinery means proper lubrication, good maintenance and skillful handling. Safe care of manpower means avoidance of accidents. Together they are an unbeatable team which speeds the construction industry's huge war-winning job.

ARMY E NAVY

Bucyrus-Erie

SOUTH MILWAUKEE, WISCONSIN, U. S. A.



FROM A RECENT REPORT

". . . So soldiers were set to tunneling. It was a major mining job for they had to bore through solid rock using air drills and dynamite. . . . They bored four great tunnels into a mountainside, each one as wide as an automobile and some over 50 yards long . . ."

Serving BOTH FRONTS

America's 1942 ore production was enormous. 1943 goals are even higher. In order to meet these staggering requirements, mining men are insisting upon reliable rock drills with high drilling speed and low upkeep cost. The Army and Navy also require drills with the same footage-producing characteristics—rock drills that will do the best job on urgently needed air bases, tank traps, tunnels, fortifications, and strategic highways. Ingersoll-Rand Rock Drills are serving both fronts.

Performance figures from many mining, quarrying, and construction jobs have proved that there are more feet drilled per shift when I-R Jackhamers, Drifters, and Stopehamers are used. As a result, the demand for these machines is greater than ever before. Although production problems are tremendous, we are proud to say that we can usually supply both the home front and the war fronts.

If you need drills, bits, or other rock drilling equipment to help produce more of the ores vital to our war effort, your orders will receive prompt attention.

5-337

Ingersoll-Rand
11 BROADWAY, NEW YORK 4, N. Y.

COMPRESSORS • TURBO BLOWERS • ROCK DRILLS • AIR TOOLS • OIL AND GAS ENGINES • CONDENSERS • CENTRIFUGAL PUMPS

TIP ON MAXIMUM DRILL STEEL SERVICE

HOW TO *Heat-treat* HOLLOW DRILL STEEL

To get the longest service from Bethlehem Superior Hollow Drill Steel, we recommend the following heat-treatment:

To harden a bit, heat it uniformly to a temperature of 1430 to 1450 deg. F. for a distance sufficient to overlap the portion heated for forging. Then quench in a flood of clean, cold water to a depth of about ½ to ¾ inch. If desired, an 8 per cent brine solution may be used as a quenching medium. It is not necessary to temper the quenched bit.

Many blacksmiths in the field are of the opinion that the heat-treatment of a bit should be varied to correspond with the type of rock to be drilled. While there is perhaps some basis for this opinion, we believe that the recommended practice given above will produce the best general-purpose bit.

The shank end of the drill rod should be heat-treated by heating approximately 2 inches of its length to 1550 deg. F., and then oil-quenching. If the drilling is severe and high-pressure hammers are used, the shank end may be heated to about 2 inches below the lugs or collar and quenched from 1550 deg. F. in oil. Either of these treatments produces sufficient hardness and toughness without tempering.

The threaded ends of fabricated rods for use with detachable bits should be treated in the same manner as the shank ends. Heat about 1 inch above the threads to 1550 deg. F. and quench in oil.

BETHLEHEM SUPERIOR
HOLLOW DRILL STEEL

BETHLEHEM STEEL

This is Synthetic Rubber

Synthetic rubber is a new basic raw material which is processed, treated and formed in much the same way as natural rubber. And...like natural rubber...it is of different types, is capable of many variations.

Synthetic rubber is manufactured from gasoline, alcohol, coal and gases kept liquid under pressure and is now being made in five basic commercial types. Each type has distinct properties and characteristics that fit it for specific tasks. For some, synthetic rubber is superior to natural rubber. For others it is equally as good.

To determine which synthetic rubber is right for the job, however, requires a really thorough knowledge of rubber chemistry. The manufacturer must be familiar with the properties of all five commercial types ... Buna-S, Buna-N, Neoprene, Thiokol and Butyl.

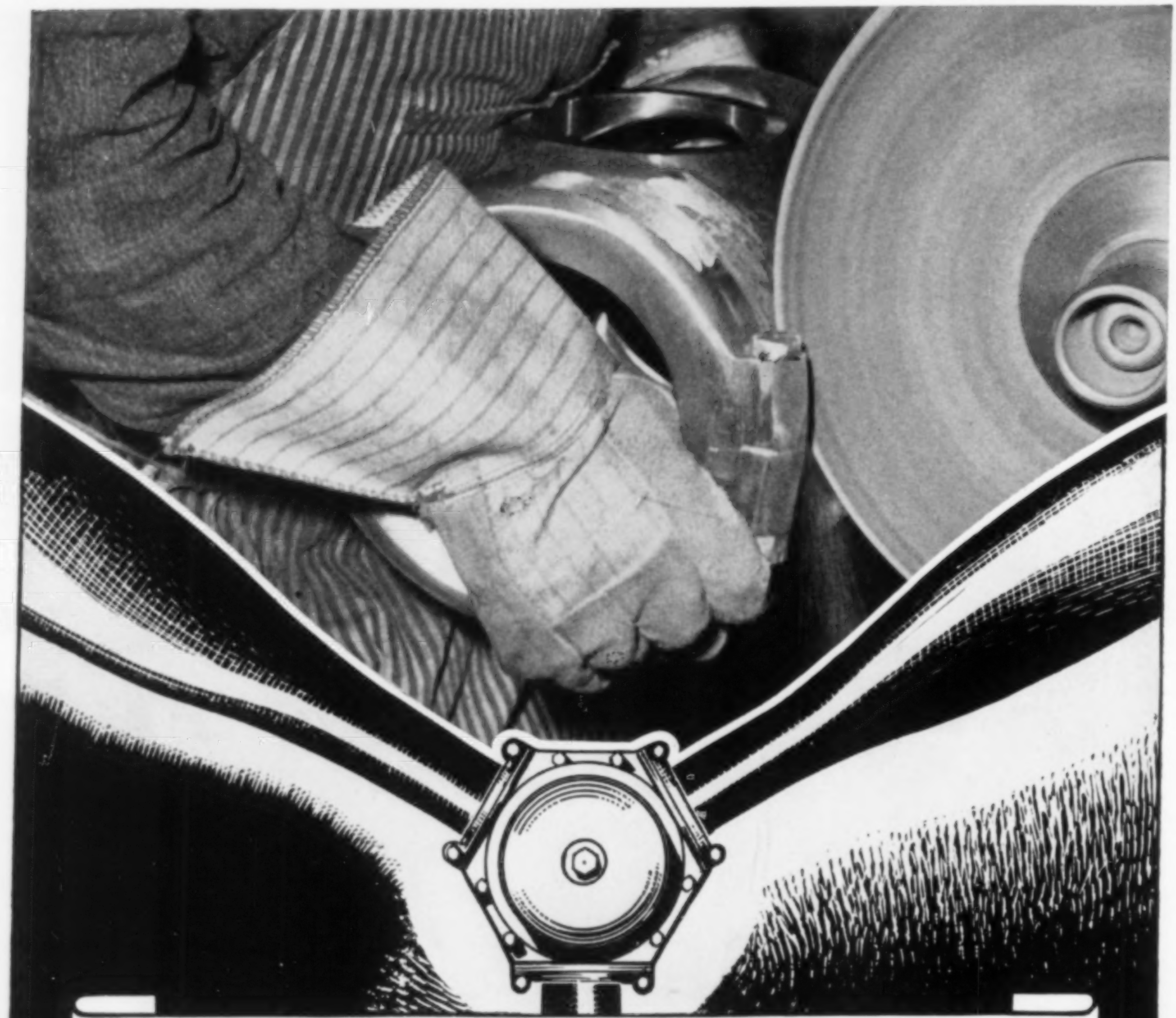
United States Rubber Company uses all five basic types of synthetic rubber and is thoroughly familiar with the characteristics, properties and suitability of each type to the task for which it is intended. As the nation's largest user of synthetic rubber, "U.S." has built up a tremendous backlog of knowledge of this new basic raw material and experience in processing synthetic rubber to handle a certain definite job. Today, this knowledge and experience are being drawn upon to the fullest in supplying the Armed Forces and war industries with the synthetic rubber and synthetic rubber products they need.

A copy of "The Five Commercial Types of Synthetic Rubber" will be a valuable addition to your files.

Listen to the Philharmonic Symphony program over the CBS network Sunday afternoon, 3:00 *to* 4:30 *E.W.T. Carl Van Doren and a guest star present an interlude of historical significance.*

1230 Sixth Ave., Rockefeller Center, New York 20

UNITED STATES RUBBER COMPANY



Quality Polishing at Aircraft Speeds

Calls for ALUNDUM ABRASIVE

SPEED is the watchword in everything connected with aircraft production today. That's why Hamilton Standard Propellers at East Hartford uses Alundum Abrasive for polishing this barrel and many other parts.

Special Norton crushing and screening processes control the grain size and shape of Alundum Abrasive, giving sharp, strong grains that cut fast. Special surface treatments give the grains extra capillarity—the ability to stay in the wheel head until all their work is done.

NORTON COMPANY, WORCESTER 6, MASS.

NORTON ABRASIVES

G-151

ON THE COVER

KEEPING a steady stream of tanks rolling off the assembly lines for the use of our armed forces and those of our Allies requires modern methods and equipment. Our cover picture shows how the hundreds of bolts, nuts, and cap screws needed in the assembly of these roaring monsters are quickly applied with air-powered impact wrenches. The man on the left is tightening nuts on the drive sprocket of an M-4 tank, while the other operator is running in cap screws. Practically all the other portable power tools used on this assembly line are also air-operated.

•

IN THIS ISSUE

ELECTRONICS is a new word in the layman's vocabulary that most likely will soon become as familiar as the terms "automobile" and "airplane." Electronics is not a science of recent origin, but it is a new and very flexible method by which electricity is made to do man's bidding. Our leading article discusses some of its manifold workings.

•

PROGRESS in the form of wider locomotives and railroad cars has rendered a Chesapeake & Ohio Railway tunnel through the Blue Ridge Mountains of Virginia inadequate for modern needs. It would have been too difficult to enlarge the old bore and maintain traffic, so a new one, described by A. W. Loomis, is being built. It has been holed through since our article was prepared.

•

IN THIS issue Paul Hoffman concludes his exposition of the engineering principles involved in the supercharging of airplane engines. His first article was published in May.

•

MOST mining operations are complicated because of the necessity of eliminating permeating ground water, and the deeper the workings go the greater the problem becomes. At Butte, Mont., the Anaconda Copper Mining Company has recently put in service a central drainage and pumping system that will make it possible to dewater virtually all the mines in the area through one shaft, thereby effecting considerable savings and increasing mining efficiency. The new pump station is described by Marcus McCanna.

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A monthly publication devoted to the many fields of endeavor in which compressed air serves useful purposes. Founded in 1896.

CCA Member Controlled Circulation Audit.

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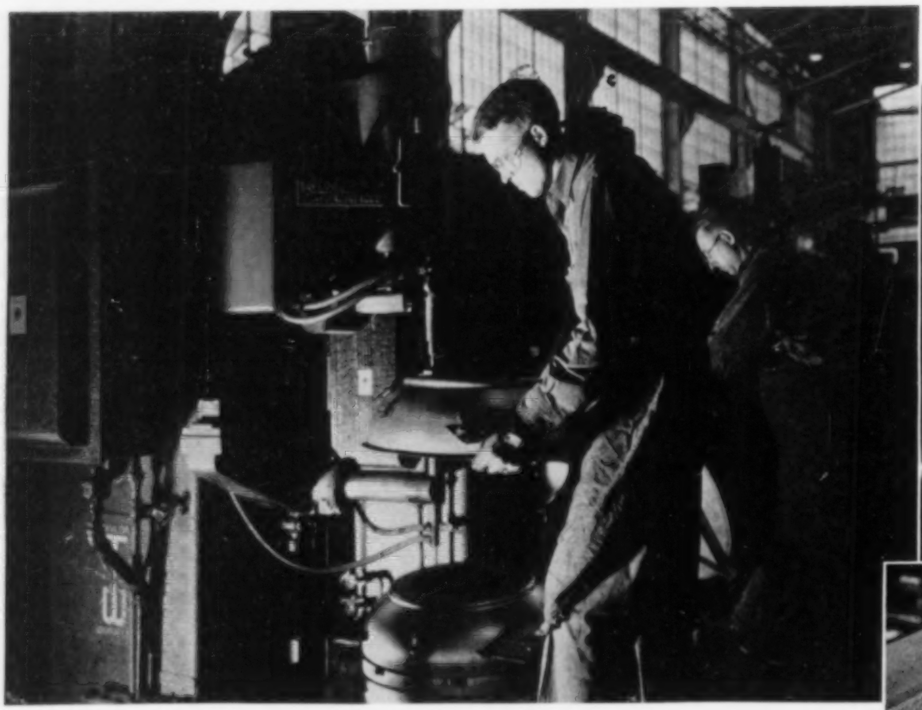
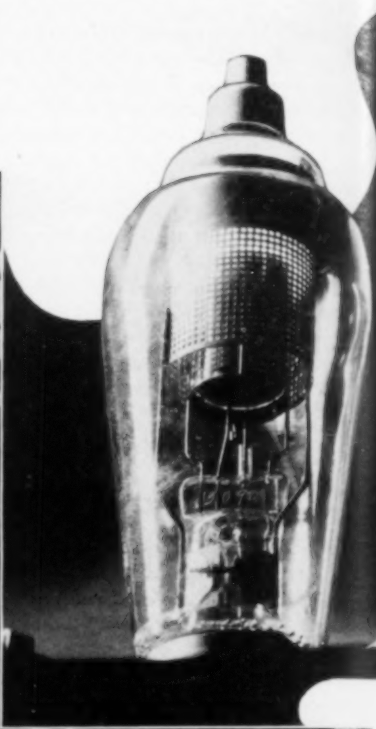
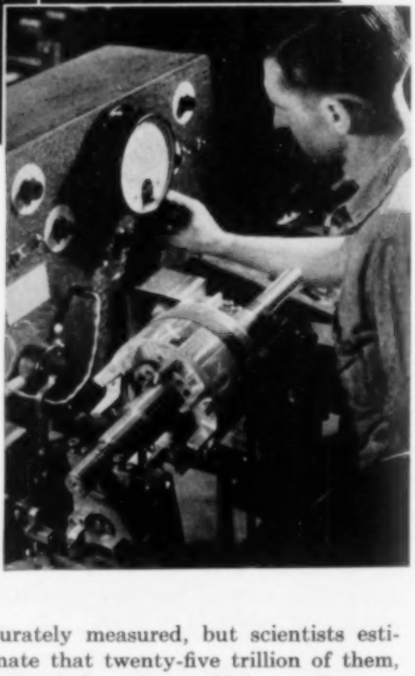
Magic from Vacuum Tubes

C. H. Vivian







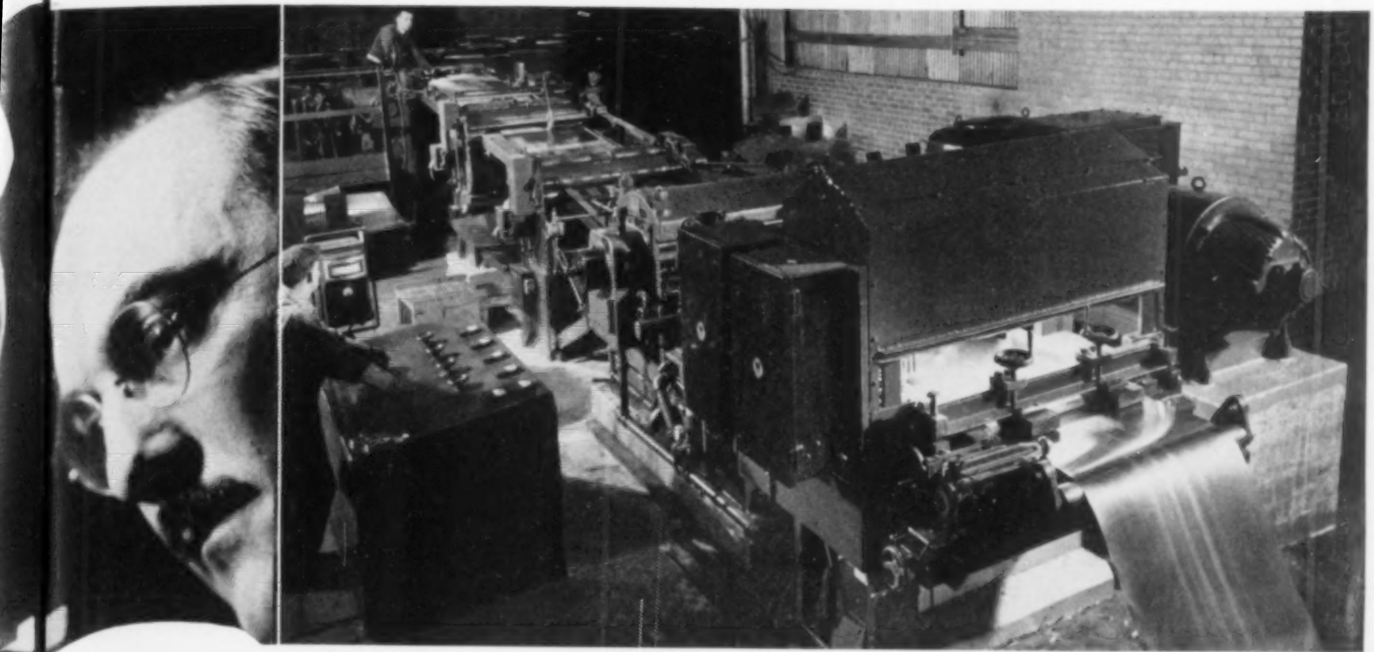
APPLICATIONS OF ELECTRONIC TUBES

The electronic tube (top, center) is a modern magical wand that has revolutionized countless industrial processes and holds the promise of even greater accomplishments in the future. The air-operated spot-welding machines pictured above are precisely controlled by a sequence timer that regulates the flow of current to the welding points and the number of their strokes per minute. At the right is shown an electronic dynetric balancing machine. A stroboscope indicates the part of the revolving rotor that is out of balance and registers the amount of unbalance on a meter. Such machines make it possible to correct accurately and quickly any vibration in crankshafts, propeller blades, fans, and other mechanical parts or units. On the opposite page, top, an electric eye is inspecting tinplate while running through a shearing line at the rate of 1,000 feet per minute. Holes that are invisible to the human eye are automatically detected and marked, thus protecting canned goods from leakage and spoilage.

IN THE year 1756, Benjamin Franklin advanced the theory that "electric matter consists of particles extremely subtle since it can permeate common matter, even the densest, with such freedom and ease as not to receive any appreciable resistance." No one paid much attention to the statement, and during the next 100 years scarcely a mention was made of "electric particles." Recently, however, they have projected themselves into the news, for it is they that form the basis of the newly acclaimed science of electronics.

The particles that Franklin's inquiring mind comprehended but didn't understand were electrons, which we now recognize as being one of the fundamental constituents of all matter. Together with protons and neutrons they make up atoms. Protons and neutrons form the nucleus of each atom, and the protons contain a positive electrical charge. Electrons revolve around the nucleus in definite orbits similar to those of our planetary system and bear a negative electrical charge. The 92 chemical elements of which every material substance is composed differ greatly in mass and complexity. The simplest of them all is hydrogen each atom of which has a nucleus of one proton, which holds one electron in the surrounding orbit. Then comes helium, with a nucleus of two neutrons and two protons accompanied by two electrons. Proceeding up the atomic scale to uranium, the 92nd element, we find an atom having a nucleus of 92 protons and 146 neutrons surrounded by a swarm of 92 electrons. In every case there are as many positively charged protons as there are negatively charged electrons, and because of this balance the electrical nature of the material is not revealed unless the atom is torn apart. Electrons have never been accurately measured, but scientists estimate that twenty-five trillion of them, laid side by side, would form a line one inch long.

The ordinary electrical circuit transmits electrons through copper wire and, under such conditions, the electrons are confined. The science of electronics introduces a new angle, that of passing electrons through space such as that within a vacuum tube. The electrons are then "free" and can be controlled so that they will respond to light, voltage, or the lapse of time. These new types of control make it possible to perform many electrical functions that were not feasible previously, or to perform other tasks better or more easily than by methods hitherto available.



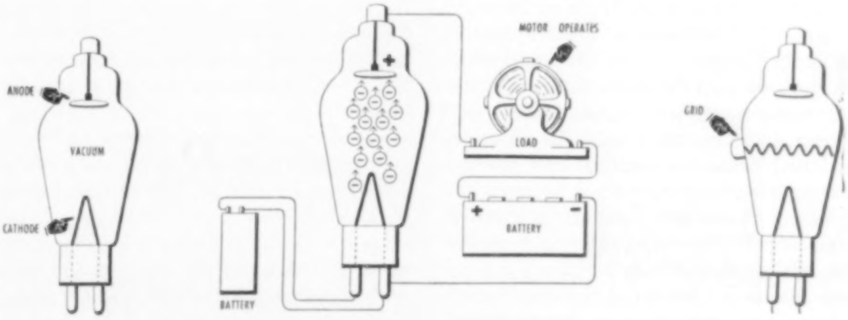
All illustrations, Westinghouse

A popular definition of electronics is, then, that it is electricity freed from the bondage of wires. In the simplest form of electron tube or vacuum tube there are two electrodes with an evacuated space between which may or may not contain some inert gas. By heating one of the electrodes—the cathode—negatively charged electrons are liberated from the metal of which it is composed. If the second terminal, called the anode, is given a positive charge, the highly mobile electrons will be attracted to it and will leap across the space to reach it.

The flow of electric current that is thus set up is no different than that passing through a piece of wire. However, because of the fact that the electrons within the tube are free, it is possible to control them with great speed and accuracy and, consequently, to modify the current almost at will. This is done by interposing another electrode, called a screen or grid, between the cathode and anode and applying to it the desired voltage. It is therefore apparent that, if an electronic tube is connected to an ordinary electric circuit, means are at hand to vary the flow in an infinite number of ways not feasible when the current is carried through wires alone. An endless variety of tubes is used bearing names such as diode, triode, pentode, ignitron, thyratron, phanatron, phototube, beam-power tube, cathode-ray tube, etc. The type chosen depends upon the currents and voltages involved and upon the speed of control desired, plus the function to be obtained. This speed can be up to a billion times a second. Electronics is a popular name that has caught the imagination of the public and will probably stick. Technicists have another name, thermionics, which is strictly defined as the science dealing with the emission of electrons from hot bodies but which is generally applied to the broader subject of the subsequent behavior and control of such electrons.

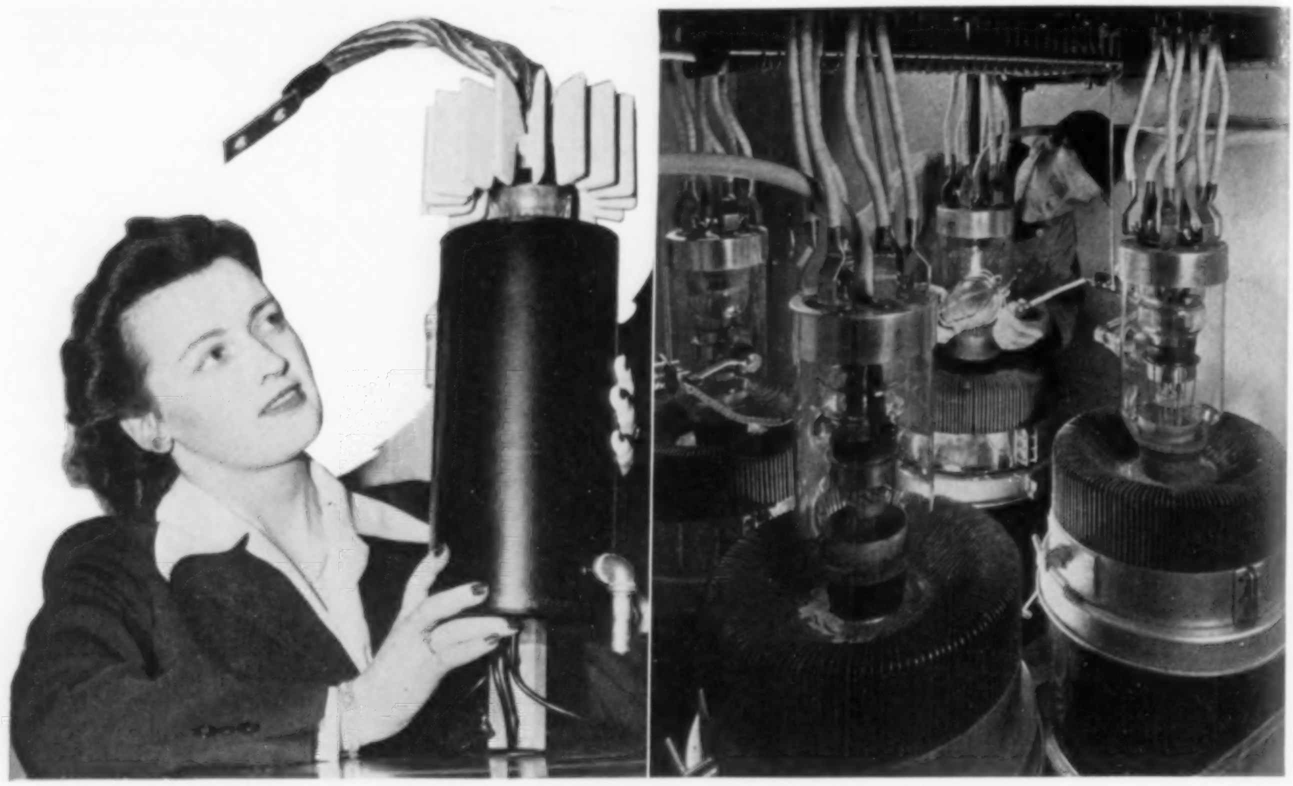
Electronics is not new, but many of its present applications are new. While working on his incandescent lamp in 1883, Edison accidentally discovered that electricity flowed between the lamp filament and an independent cold electrode in the same bulb when the electrode was made positive with respect to the filament. This phenomenon was given the name "Edison effect." The term "electron" was originated by George J. Stoney in 1891 to designate the elementary electrical charge. In 1895, W. C. Roentgen discovered the X-ray, and the tube in which these rays are produced ranks as the first electronic tube made. Four years later J. J. Thomson conducted experiments that identified photoelectric emissions as electrons, and in 1900 he advanced the electron theory. He also proved that cathode rays (electrons) come out of all sorts of substances when they are made cathodes in the passage of an electrical discharge through highly exhausted tubes, and further showed that the mass of each electron is of the order of one-thousandth of the mass of the hydrogen atom.

In 1909, Robert A. Millikan proved Franklin's contention that electrical



HOW AN ELECTRONIC TUBE FUNCTIONS

At the left is a simple 2-element vacuum tube containing two electrodes—a cathode and an anode. In the center it is shown connected in an electrical circuit between a battery and a motor, with one power lead attached to the anode and the other to the cathode. When the latter is heated by the current and the anode is given a positive potential, negatively charged electrons are emitted from the cathode and travel at tremendous speed to the anode. This closes the circuit, operating the motor. It should be noted that the direction of flow is just the reverse of the orthodox current flow from anode to cathode. By inserting a grid (right) between the cathode and anode and by applying voltage to it the flow of current through the tube can be controlled, as desired. This is the basis of electronic-tube functioning. There are, of course, many types of tubes and many possible variations in hook-up. By suitably combining these, the electrical engineer can cause a tube to rectify, amplify, generate, or control current; or to transform light into current or current into light.



TYPES OF TUBES

The bomb-like tube that the young lady is holding is an ignitron, which converts alternating current into direct current. Ignitrons are widely used in industry, notably in the manufacture of aluminum and magnesium. At the right are four air-cooled 50,000-watt tubes that furnish power for a radio broadcasting station. Two of them are spares that can be placed in service merely by pushing a button and without interrupting transmission.

charges are made up of discrete elements or particles (electrons) and that these are all alike. This was done by means of what has come to be known as the "famous oil-drop experiment." Seeking the smallest possible observable body of matter that could be given an electrical charge, he converted the oil into a mist by spraying it with an air stream from an atomizer. The minute, nonevaporable, spherical globules thus produced were introduced into the space formed by two circular, horizontal brass plates held about 16 millimeters apart by three insulating posts. A constant and uniform electrical field was created between the plates by attaching to them the terminals of a 10,000-volt battery. A puff of air and oil was directed toward a point just above a pinhole in the upper plate while the battery was disconnected. Some of the droplets found their way through the hole into the intervening space. In order that they might be observed, a powerful beam of light from an arc was passed between the plates and a short-focus telescope was set up looking through a window and in a direction almost at right angles to the beam.

To quote Mr. Millikan: "In this beam the droplet appeared like a bright star floating downward toward the lower brass plate. Before it struck the plate, the switch was thrown so as to create the electric field between the plates. The droplet, if properly charged by the frictional process involved in blowing the spray, would then begin to rise against gravity, because of the pull of the field upon its charge. Just before it could strike the upper plate, the field would be thrown off by opening the switch, and the droplet would begin to fall again at exactly its former rate. Its successive times of fall under gravity and of subsequent rise under the action of the field were then taken."

Seventeen readings showed a variation of only 4/10 second in the time it took the droplet to fall a distance of 0.5222 centimeter (0.2 inch), the mean time being 13.595 seconds. In the same manner was observed the time it took the droplet to rise under the action of the field. Between successive upward trips, the charge on the droplet was progressively modified by passing underneath it a beam from an X-ray bulb. This resulted in changing the time required for the rise, but it was observed that "only a few definite times of rise seem to be possible, and these recur continually, thus indicating that only certain definite charges can be placed upon the drop. These charges are proportional to the speed imparted by the field and, since the action of the field is first to neutralize the downward speed imparted by gravity and then to impart an upward speed in addition, the total speed imparted by the field is actually obtained by adding the downward speed and the upward speed." When this was done, it was found that the speed had increased in terms of simple arithmetic progression corresponding to the increase in charge between successive upward trips. This proved that the charges which the droplet was able to carry under these different conditions showed very definite unitary relationships.

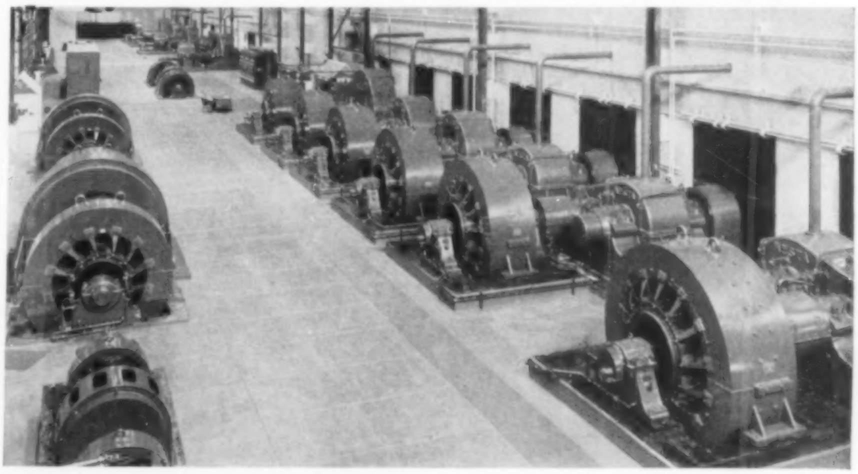
Millikan's experiment was repeated with thousands of drops of varying substances, and the outcome was always the same. Accordingly, the conclusion was reached that all electrical charges are built up out of a definite number of discrete elements or particles, all exactly alike. Millikan's work started a real flood of research in electronics that has brought forth the numerous devices which, combined with electrical circuits, make it possible to perform almost any electrical function. As a result of their application there has been a greater advance in engineering, communications, and industrial processes during the past 25 years than ever before in a similar period.

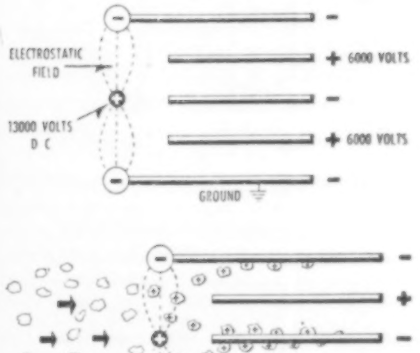
The great electronic development that came out of World War I was the radio. Commercial broadcasting is such a familiar thing to us now that it seems difficult to realize that it is only 23 years old, the first regular, prescheduled programs having started on November 2, 1920, at Westinghouse Station KDKA in Pittsburgh, Pa. At the present time, there are some 55,000,000 receiving sets and 900 commercial broadcasting stations in the United States. When the present war broke out, the radio-manufacturing industry was employing 500,000 persons and doing an annual business exceeding $1,000,000,000. The last important peacetime development in radio was frequency modulation, which is now being used by 41 commercial stations. The human ear can hear vibrations ranging from 16 to 16,000 per second; but, until this improvement came along, the radio could reproduce only those up to 5,000. Frequency modulation puts them all in, giving voices and music greater fidelity.

For the present, the radio industry is fully engaged in war work. Much of its activity is shrouded in secrecy, but we are promised that some of the startling new developments now being put to military uses can be readily converted to peacetime services that will have a great effect upon our daily lives. We are told, for example, that ships will no longer collide with other vessels or with icebergs, that airplanes will cease to crash into heights obscured by fog or darkness, and that trains will be stopped from running into others on the same track—all through the automatic functioning of electronic tubes.

One modern electronic miracle is the electron microscope which has been placed in a number of industrial, medical, and institutional laboratories during the past two years. It has already been developed to the point where it will produce magnifications 100 times larger than those that can be obtained with a light microscope. A theoretically perfect instrument of this type would give useful magnifications of the order of 200,000,000 diameters, or 100,000 times greater than the 2,000-diameter enlargements possible with the finest optical microscope. It is doubtful, scientists say, if anything approaching this perfection will ever be achieved. The electron microscope is based on the principle that an electron in motion may be deflected by an electrostatic or electromagnetic field, just as light rays are deflected by a glass lens. Electrons liberated by a heated cathode are passed through the object to be examined, and in so doing they take on its characteristics. They are then spread apart to produce an enlarged electron image of the material on a photographic plate or fluorescent screen. Much is expected of the new instrument in the fields of chemistry, bacteriology, and metallurgy.

The numerous functions or duties that electronic tubes can perform may be grouped under six general headings: they can rectify, amplify, generate, and control current; convert light into current; and convert current into light. Almost all power is now generated in the form of alternating current, but there are many services for which direct current is necessary or desirable. To supply these demands it has been customary to convert alternating into direct current with motor-generator sets. This can now be accomplished electronically. Peter Cooper Hewitt, an engineer of the Westinghouse Electric & Machinery



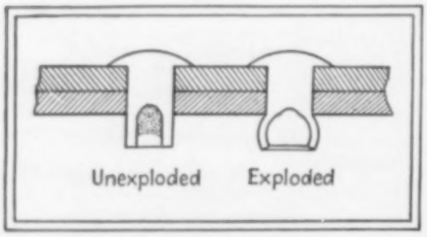


CLEANING AIR ELECTRICALLY

At the top is a steel-mill motor room that is kept dust-free by precipitron units, as shown at the left. These electric air cleaners remove dust particles as small as 1/250,000 inch and prevent damage to motor windings. Where precision work is carried on, they catch abrasive particles that might scratch highly polished surfaces. They speed heavy welding operations by ridding the air of fumes and smoke. In one plant where high-speed cutting and grinding tools are operated, they remove daily as much as 100 gallons of oil that floats in the air in the form of mist. The line drawings illustrate the principle on which the precipitron operates. The rectifying property of electronic tubes is used to create an electrostatic field at the entrance to the units by applying a 13,000-volt charge of direct current to tungsten wires. Collector plates are also given a potential of 6,000 volts, direct current. When incoming air passes through the electrostatic field, suspended particles receive a positive charge, and when they reach the collection chamber they are attracted to and deposited on negative plates.

Company, discovered and patented the rectification properties of the mercury-vapor arc lamp in 1902. However, trouble known as arc back was sometimes experienced through the reversal of the usual flow of current from cathode to anode. This was largely overcome by the development of electronic rectifiers. This new device was at first adopted more generally in Europe than in this country; but in recent years there has been a strong tendency here to make use of it. The ignitron rectifier brought out by Westinghouse in 1937 has been produced so far for handling 2,250,000 kw. of current in the United States and Canada. Enormous quantities of direct current are needed for manufacturing aluminum and magnesium, and this is being supplied in our war plants almost entirely by electronic rectifiers. Other large users of direct current are traction systems, steel mills, electroplating plants, and ore-treatment mills. Rectifiers also provide high voltage for radio transmitting stations. Another device that utilizes the rectifying property of electronic tubes is the precipitron which cleans air electrostatically.

The second basic thing electronic tubes can do is to amplify current. This is accomplished by inserting a grid between the cathode and anode. If a faint radio signal or some other weak voltage impulse is led into the grid and given a positive potential, it increases the flow of electrons from cathode to anode and amplifies the power, which passes on to the anode and thence into the circuit. This property has such practical applications as making radio and radiotelephone contacts between ground stations and planes, between ships and shore, between troops and their headquarters, between tanks and their commander. It also permits the pilot of a commercial plane to turn on seadrome lights by radio signal to make a night landing.



ELECTRONIC RIVETING

In assembling one of the largest of our all-metal bombing planes, about 10,000 aluminum rivets must be driven at points that are accessible from only one side. The explosive rivet was developed for use in such places. The explosive is contained in a small cavity in the inaccessible end of the rivet and is detonated by heat, expanding that end as shown in the drawing. Detonating heat was originally transmitted through the rivet by holding against its head a hot metal tool similar to a soldering iron, but a superior electronic method is now available. By utilizing an oscillator in conjunction with an applicator, radio waves are concentrated in the rivet head and generate eddy currents that produce heat. As many as twenty rivets a minute can be detonated. They are inserted ahead of time and are held in place by Scotch tape.

Amplifying tubes, termed repeaters, enable us to carry on telephone conversations over long distances by periodically renewing the strength of the currents, which would otherwise become too weak to actuate the telephone receiver. Mechanical repeaters were used from 1904 on until Dr. H. D. Arnold made improvements in the audion tube invented by Dr. Lee deForest. In 1942 there were 123,000 repeaters installed in the Bell Telephone System, and these required more than 400,000 tubes. A conversation between persons in Bangor, Me., and San Diego, Calif., for example, travels nearly 4,000 miles and passes through more than 200 amplifiers with a total of 600 tubes in tandem. The control of the amplification is effected automatically by electronic devices. Radiotelephony also makes use of electronic tubes. Overseas service was inaugurated in 1927 between New York and London and has now reached a stage of development which, save for the war, would permit connecting any telephone in the United States with 93 per cent of the phones in other parts of the world.

In industry, minute machine impulses can be intensified so that they can be registered on oscilloscopes for measurement and study. Crankshafts and other machinery parts, or entire mechanisms, can be precisely balanced dynetrically and airplane propellers can be tested for vibration.

Geophysical prospecting for oil, which has removed much of the gamble from the search for petroleum, depends largely upon electronic amplifying devices. In the widely used reflection-seismograph method, tubes pick up the feeble waves transmitted through the earth from controlled dynamite explosions and amplify them so that they may be transferred to paper by photographically recording galvanometers. By making a number of these "seismograms" along a circular path around each explosion, it is possible to distinguish between direct, reflected, and refracted waves, and this information enables geologists to tell much about the structure of the underground strata.

Third on the list of essential duties these wonder tubes can perform is that of generating alternating current of very high frequencies—up to millions of cycles per second. This is done by amplifying direct current and then feeding part of the amplified voltage back into the tube through a grid. By repeating this cycle over and over, alternating current is produced. This so-called ultra-high frequency current furnishes the power for radio transmitters and is used in many other ways. One of its newest applications is that of applying heat quicker than it can be done by any other means. In our May, 1943, issue is a description of the manner in which plywood is thus bonded together in a fraction of the time required when the work was done with steam heat. Similarly, plastic forms are now cured in minutes instead of hours. The new heat source is also enabling us to spread our reduced tin supply so that it will meet our needs. Steel engineers have developed a method by which steel plates can be coated with a film of tin only thirty-millionths of an inch thick. This is done by flowing it—evenly and smoothly—at a rate approaching 1,000 feet a minute. As a result, each pound of tin now covers an area that formerly required 3 pounds. As much high-frequency power is used in a single tinplate mill as in all our commercial broadcasting stations!

Again, this almost instantaneous heating makes possible faster and more uniform heat treating, annealing, brazing, welding, and soldering. One end of a nail can be made red-hot so quickly that the other end remains cool. This means that metal parts can be casehardened without affecting the underlying metal and that certain areas can be hardened while surrounding ones, just ¼ inch away, are left relatively soft and tough.

The principle of high-frequency generation is also applied to what is known as carrier-current transmission. Its use, in connection with protective relaying, has increased the capacity of our power lines by 50 per cent, with attendant important economies in copper, aluminum, and other vital war metals. Carrier-current transmission is likewise utilized in telephone and telegraph circuits, single wires being made to carry multiple messages at the same time by using different frequencies. The resultant saving in copper in our national telephone system since 1915 is estimated at 1,500,000,000 pounds, or the equivalent of a year's output of all our mines.

The fourth broad field of usefulness of electronic tubes is that of regulating the flow of electric power. This is done by connecting the control circuit in such a way that it becomes a function of temperature, speed, time, or of some other variable. This varies the voltage on the grid and results in automatically increasing, decreasing, or stopping the flow of electrons and doing it with split-second timing and great precision. Among the important applications of this function is that of controlling resistance welding with great exactitude. The welding of heavy metal sections presents no problems, as they can stand overheating and warping, but the fabrication of thin sections of aluminum alloys that enter into the construction of airplanes calls for exact timing of the welding process, even down to onehundredth of a second. The new electronic technique regulates the current and electrode pressure so closely as to produce uniformly high-strength welds. It acts so fast that airplane subassemblies are literally "sewed" together with as many as 1,800 electrical stitches a minute.

The same sort of control can be exerted on motors. In fact, this application is about ten years old. It permits operating direct-current motors with alternating current and provides a better means of regulating their speed than does the conventional rheostat method. This is especially valuable in the case of many machine tools. For example, the speed of a grinder headstock can be varied to suit any type of grind. The smooth, gradual acceleration that is possible prolongs tool life and improves the quality of the work done. Thus far, this type of control has been built for only relatively small motors (up to 15 hp.), but it will be extended to larger sizes in the future. It is expected that motor control will become common practice in printing, steelmaking, and papermaking plants.

The fifth type of service electronic tubes can render is that of transforming light into electric current. This is accomplished by replacing the heat-activated cathode of the tube with one made of photosensitive material. Light, instead of heat, then stimulates the emission of electrons. The electronic emission increases in direct proportion to the amount of light introduced, and this in turn, with the aid of an amplifier, increases the power flowing through the circuit. An example of this photoelectric-tube action is that of the now familiar electric eye that opens and closes doors, sorts peanuts, oranges, and numerous other food products, and counts traffic and inanimate objects with unfailing accuracy. A recent development of the same type is a device that detects pinholes in metal strip as it comes from the rolls and marks defective sections for rejection by automatically operating a relay, or even energizing a rejection control that throws out defective sheets from prime sheets. Television projection is another offspring of electronic tubes of this kind, as is likewise the scanning of the sound track of motion-picture films.

The modern technique of sending photographs by wire or radio and of transmitting facsimile telegrams also stems from the photoelectric tube. Curiously enough, facsimile transmission was conceived 50 years ago before the vacuum tube made its appearance, but it was put to little use because the matter to be dispatched had to be especially prepared and because means for amplifying the signals so that they could be sent long distances were then unknown. The photoelectric tube satisfactorily scans almost every kind of copy without special preparation, and amplifying tubes have solved the problem of transmission. The sending of pictures by wire originated in Europe, where Prof. Arthur Korn, in 1912, established a network that operated on a commercial basis between London, Manchester, Paris, Berlin, Copenhagen, and Munich. The first photographs transmitted for newspaper publication in this country were sent from the Republican National Convention at Cleveland in 1924. Various news-gathering agencies and even some individual newspapers now maintain transmission stations throughout the world. The Western Union Telegraph Company has developed automatic facsimile transmitting and receiving machines that operate at a speed of about 14 square inches per minute, which is equivalent to approximately 140 words of single-spaced typewriting.

The final general function of electronic tubes is the transforming of current into light. The most common examples of this field of application are the X-ray tube and the fluorescent light. The industrial X-ray, using voltages of 300,000 or higher, serves widely in inspecting castings and welds for hidden defects. A new but related type of tube is the Sterilamp, which gives off ultraviolet rays that are destructive to bacteria and other microscopic forms of life. These lamps are rendering invaluable service in operating rooms in hospitals and in food-processing establishments.

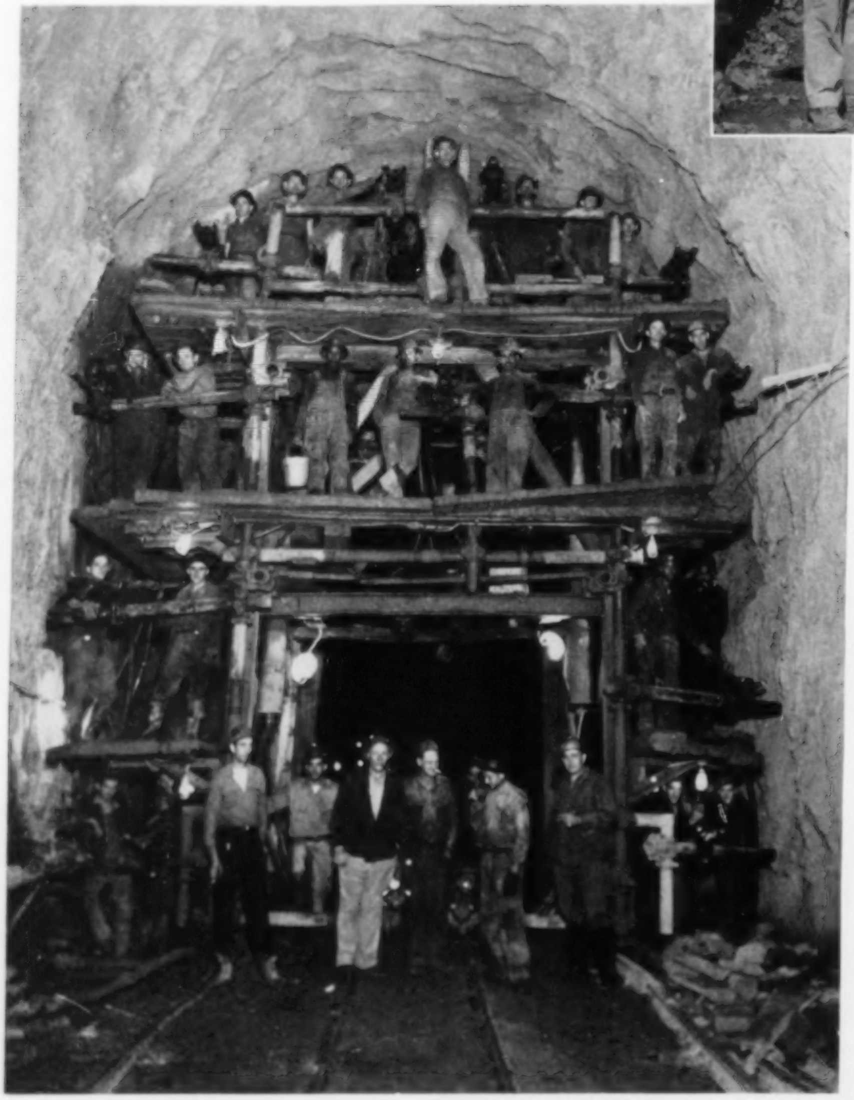
Electronics is already big business, sales of equipment during the past three years having amounted to an estimated $500,000,000, excluding radio. Some of these devices have replaced conventional types of apparatus that were not available because of wartime restrictions. When peace returns, many concerns will be faced with the problem of making a choice between mechanical and electronic equipment, and their decisions will rest upon comparisons between the economic and functional merits of the two. Meanwhile, electronics is a glamorous term and is being hailed by many as the servant of the future. Leaders in the manufacture of electronic devices are the established makers of electrical and radio goods. However, other concerns have already been attracted by the possibilities of the industry, and still more will doubtless enter in competition when the world turmoil abates. Some optimistic persons think electronics will help solve postwar unemployment problems, just as the radio did following the previous war. Whether or not they are correct, it is certain that the harnessing of free electrons holds much in store that will greatly benefit mankind.

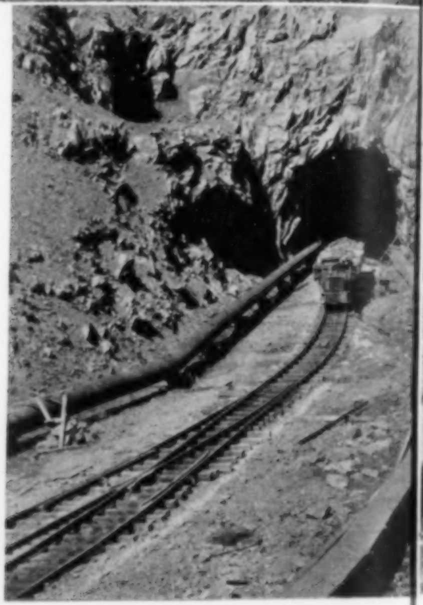
SAFEGUARDING HAZARDOUS MACHINES

A beam of light from a photoelectric tube is projected across this metal-shearing machine and prevents it from operating when hands are in the danger area.

The Blue Ridge Tunnel

A. W. Loomis





BACK in 1850, less than a century ago, the era of railroad expansion in the United States had barely begun. At that time there was in the entire country little more than 9,000 miles of track part of which belonged to a line running westward from what is now Doswell, Va., a few miles north of Richmond. The railroad passed through Louisa and extended to Mechum's River. A further extension, already underway in 1850, was to have its terminus at Waynesboro.

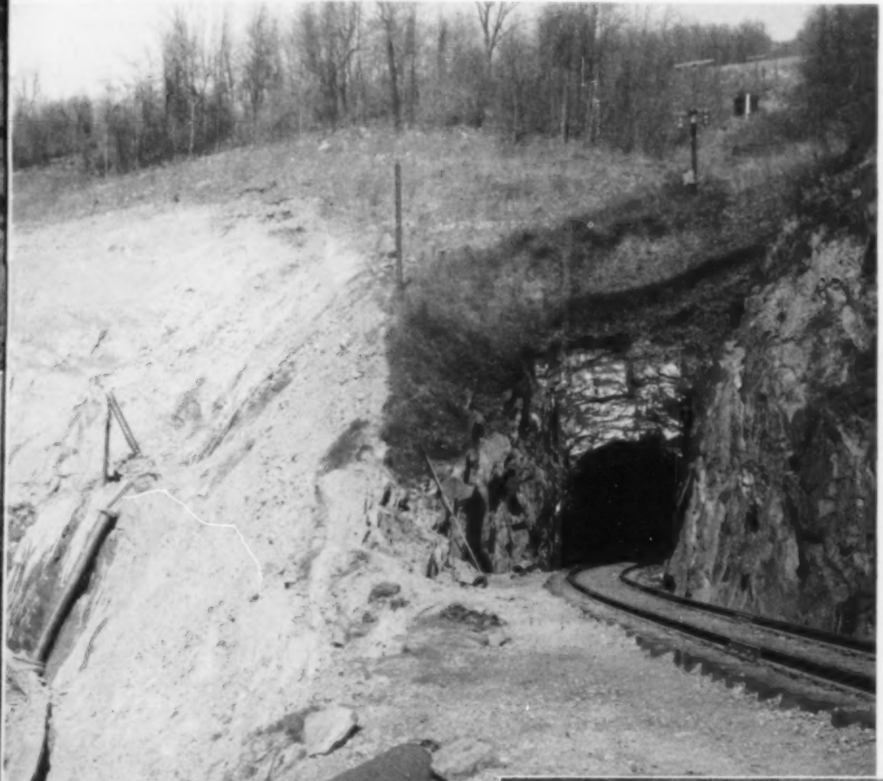
However, just east of Waynesboro, Virginia's beautiful Blue Ridge Mountains stood squarely in the path of the new line. At that time Col. Claudius Crozet was chief engineer of the Commonwealth of Virginia, and he suggested bringing the railroad to Waynesboro by means of a single-track tunnel through the mountain. The proposed tunnel was to be almost a mile long, and Colonel Crozet planned to attack the job simultaneously from both sides of the mountain. Residents of the area were startled by the boldness of the idea. Many people thought that the two bores would not meet, and numerous wagers were placed on the outcome.

But the Colonel, who had served as professor of engineering at the U.S. Military Academy, was undaunted by the scoffing; and in 1850 he started work on the project. Drilling was done with hand drills and blasting with black powder. The tunnel was completed in 1858, but in the meantime a temporary line had been built through Rock Fish Gap above the underground route and had actually reached Waynesboro four years earlier.

The tunnel represented a monumental engineering accomplishment when it was finished some 85 years ago, and it has been in use ever since. Meanwhile, the Virginia Central Railroad, as the line was known in the old days, was acquired by the Chesapeake & Ohio Railroad Company, and the tunnel became a part of the latter's main passenger route. However, with the advent of the modern locomotive and other rolling stock, its

IN CHARGE FOR CONTRACTOR

At the left are the men who are supervising the job for Bates & Rogers Construction Corporation, which is driving the tunnel under contract. Left to right they are: John Gullans, tunnel superintendent; James Strong, project manager; R. A. Chermside, general superintendent; and G. W. Robinson, office manager.

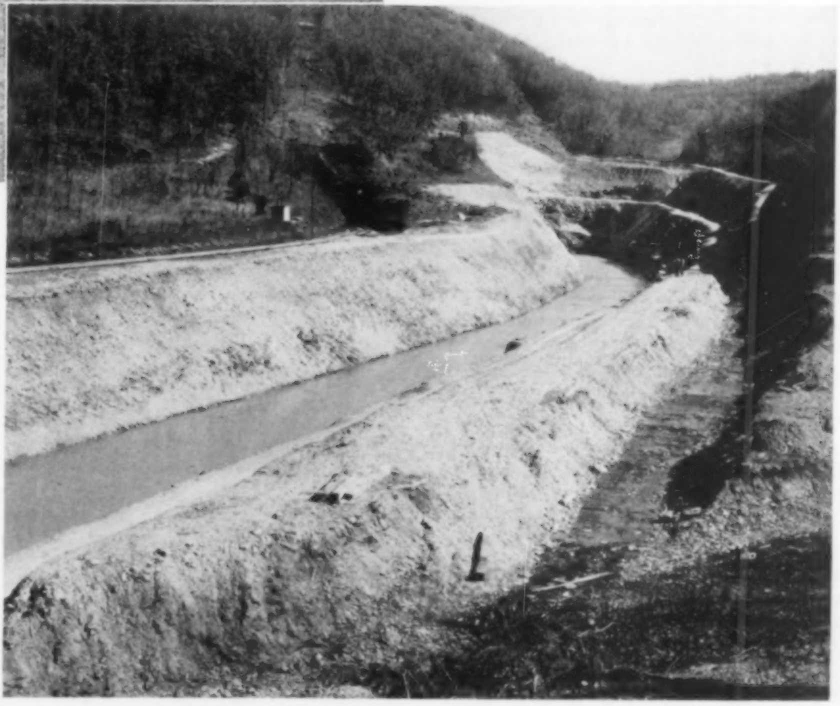


days of usefulness were over, for the bore was too small in cross section to permit their passage. It was therefore decided to cut a new single-track tunnel not far from the present one, a procedure that was deemed more feasible than enlarging the original bore for several reasons, namely, the extremely close clearances between the tunnel walls and the trains, and the impossibility of accomplishing the task without seriously interfering with wartime traffic on the line.

The old Blue Ridge Tunnel is 4,264 feet in length, has a vertical clearance from the top of the rails of about 18 feet, and a minimum width of approximately 16 feet. It is lined with brick for about 1,500 feet at its west end, the remainder being unlined. The east approach is on a 13-degree curve, which extends into the bore to a point about 100 feet from the portal. Furthermore, the tunnel slopes upward from the east portal on a gradient of 1.25 per cent, or 15 inches in 100 feet, the summit of the grade being close to the west portal.

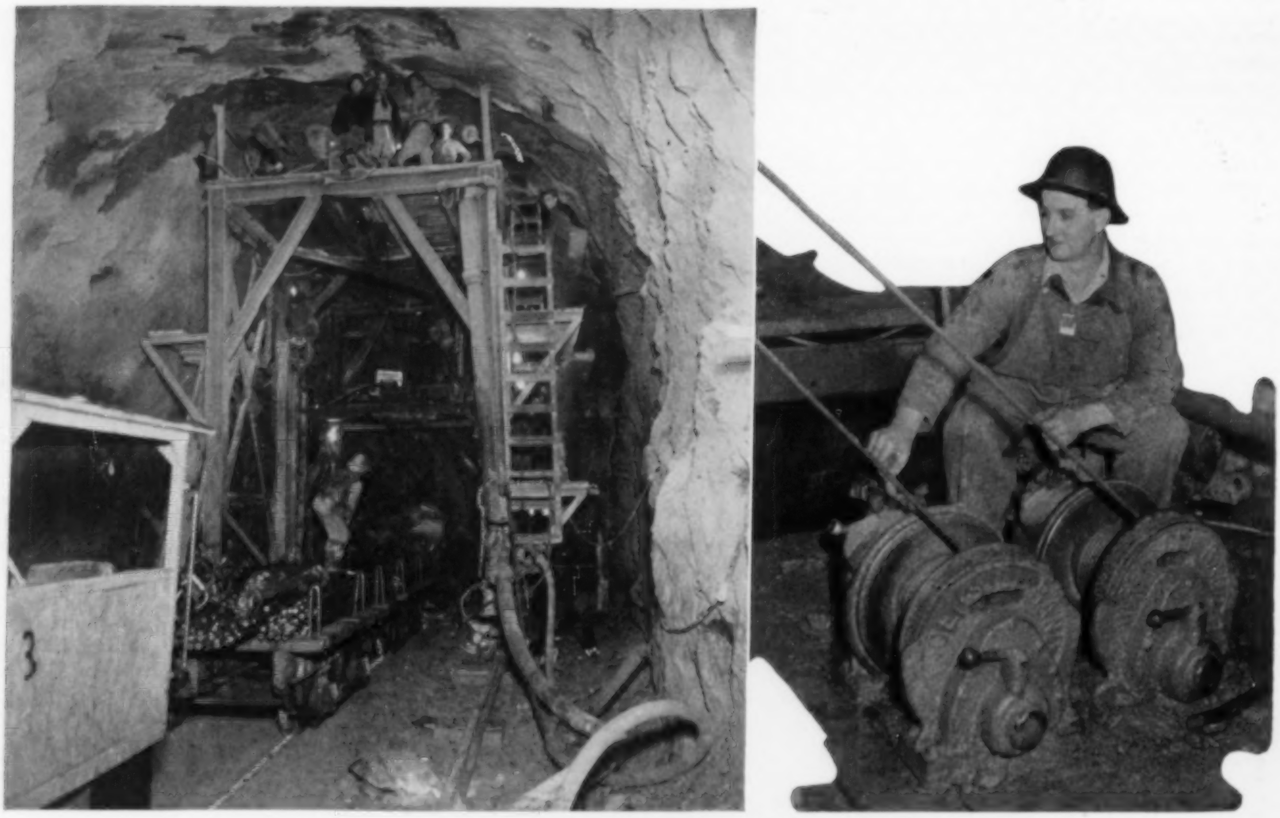
The new bore is roughly parallel to the old one, lying some 150 to 500 feet southward. It is approximately 4,000 feet long, and when lined with concrete will have a vertical clearance of 22 feet from the top of the rails and a width of 18 feet. The approach to the east portal is on a 3-degree, 15-minute curve about 2,600 feet long, and as the portal lies at its midpoint the first 1,300 feet of the tunnel is curved. From there on it is straight, except for about 100 feet near the west portal which is on a 2-degree curve. It has a gradient of 0.9 per cent, or about 11 inches in 100 feet. The east portal lies 18 feet below the corresponding portal of the old passageway, while the west portal, because of the flatter grade, is 30 feet below that of the old tunnel. The same 0.9 per cent grade continues some 2,000 feet beyond the west portal where the approach intersects the old route. The entire line revision will be about 2 miles in length.

Work on the project was started by the contractor, Bates & Rogers Construction Corporation, of Chicago, Ill., in November, 1941. It had been decided to drive the tunnel from the east end, and in this decision the following conditions were contributing factors: The approach excavations at that end would be small; work on the tunnel could proceed while the west-approach cuts were being completed; muck from the



TUNNEL PORTALS AND DRILL CARRIAGE

The picture in the center shows the east portals of the new bore (left) and the 50-year-old tunnel that it will supplant. All underground work is being done from this side to take advantage of gravity drainage. The approach cut at the western end of the new tunnel is seen directly above. It now contains water, which will be pumped out before holing through. The front end of the 3-platform drill carriage, which mounts thirteen D-505 drifter drills equipped with power feed, is shown with its crew on the opposite page.



REAR OF "JUMBO" AND "CHERRY PICKER"

The drill carriage, shown from behind, with the hinged side platforms in working position. The hoses that deliver air and water to the drills are seen at the right side of the tunnel. Underneath the carriage is a flat car loaded with drill steel and supplies. Overhead and just beyond the car is the "cherry picker" that is used to transfer empty cars from the rear to the forward end of a muck train during the mucking period. It is of the elevator type and is powered by the two air-operated hoists that are pictured at the right.

tunnel would be needed for fill for the east approaches; and the downgrade eastward would provide natural drainage and reduce the amount of power needed for hauling loaded muck cars.

The west approach is approximately 2,000 feet long and extends through shale and soft rock. The depth of the cut at the portal is 102 feet, and inasmuch as the shale material slides easily, careful backsloping and benching were required. Drilling was done with four wagon drills that were supplied with air by two portable compressors, each with a capacity of 500 cfm. Some 350,000 cubic yards of shale and rock was excavated. This was loaded by power shovels on crawler treads into 16-, 20-, and 30-yard, air-actuated, standard-gauge, side-dump cars. These were hauled through the old tunnel by a work train, and the material was used as fill at the east approach.

Actual tunneling began in May, 1942, after a narrow-gauge railroad had been constructed on the east-portal fill for running locomotives with trains of muck cars and other equipment in and out of the bore. Drilling is done from a 3-platform jumbo provided with thirteen D-505 drifters equipped with power feed. These are mounted on columns at the front of the jumbo and may be moved horizontally along the column arms or vertically on the columns themselves. The platforms at the three levels have hinged extensions that can be folded back out of the way when the carriage is being moved. All air and water connections for the drills terminate at waist level at the rear of the jumbo and are easily connected by flexible hose to the air and water lines that are carried forward as the tunnel advances.

The contractor's compressor plant is located just outside of the east portal and consists of a direct-connected diesel-engine-driven machine and six portables with a total capacity of about 3,000 cfm. These supply all the air for drilling and accessory operations, the air being delivered to the heading through a 6-inch line. An auxiliary gasoline-engine compressor furnishes air at 250 pounds pressure for starting the diesel-engine unit. The plant is also equipped with two diesel-engine-driven generator sets that supply power for a Conway loader that handles the muck in the tunnel.

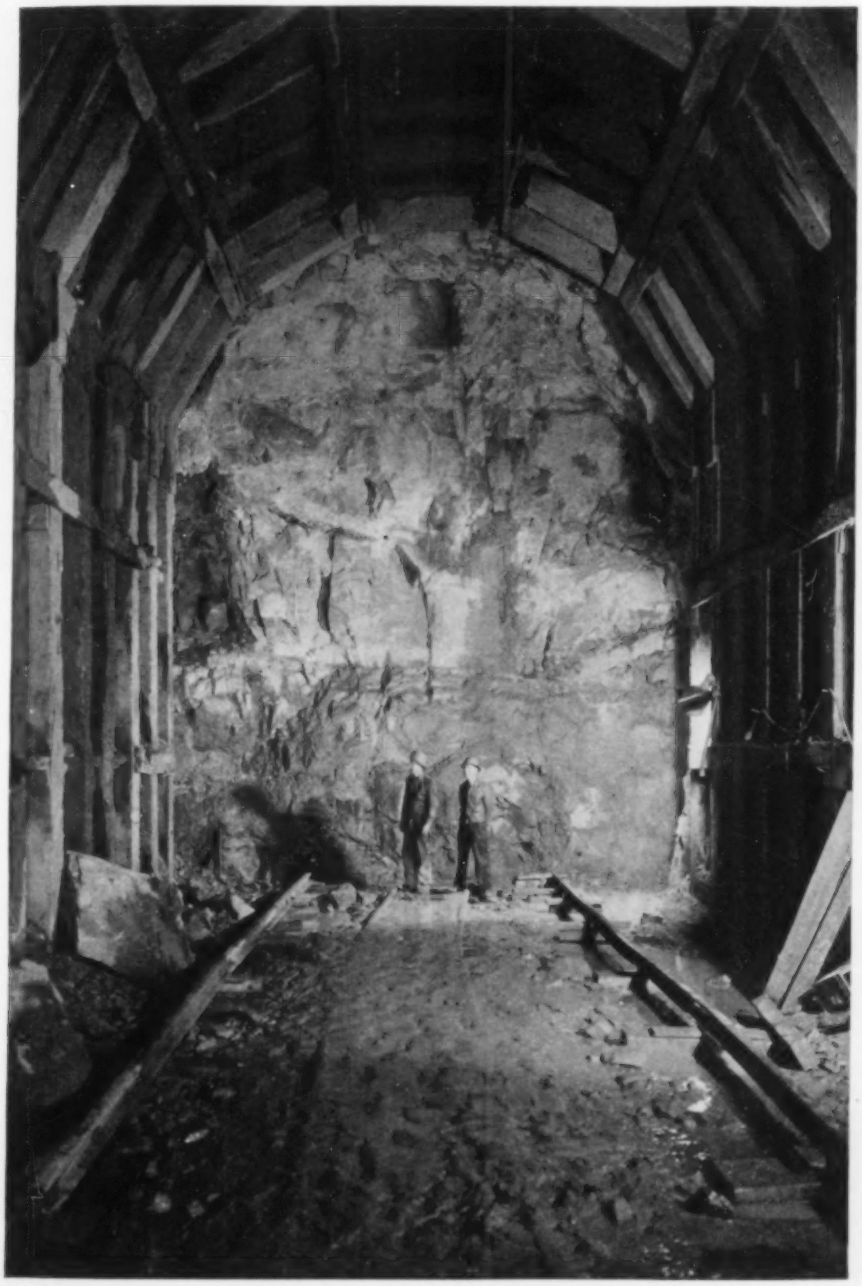
The full face of the tunnel is blasted at one time. In solid rock, excavating is done to a height of 26 feet and to a width of 20 feet. In areas of fractured rock, where timbering is required, this is increased to 28 feet and 24 feet, respectively. From 60 to 75 holes are drilled for each shot, the actual number depending upon the size of the face and the type of rock. The holes are from 10 to 12 feet deep, and each blast advances the heading from 8 to 10 feet, bringing down from 150 to 200 cubic yards of material. Drill steel with forged bits is used, the individual steels being 3, 5, 7, 9, 11, and 13 feet in length. The starting gauge is 2½ inches, and with ⅛-inch changes the gauge is reduced to a final size of 1⅞ inches.

Various kinds of rock are encountered, the hardest being a Blue Ridge greenstone and red granite. In the most-resistant of these, only 1 inch can be drilled before the bits require resharpening. However, in much of the rock they do from 4 to 5 inches, and a full 2 feet in the softer material. For reconditioning the bits, the contractor has set up a blacksmith shop at the east portal and equipped it with two sharpeners, a shank grinder, a pedestal grinder, and two oil furnaces. Other air-operated equipment on the job for general utility purposes and for service in a repair shop includes three hoists, three sump pumps, two woodborers, and an air drill.

The holes are loaded with 40 per cent

gelatine dynamite, about 5 pounds being required for each cubic yard of rock. Delayed exploders are used on some of the holes so that the rock blasted by the first shot will be out of the way when the succeeding one goes off. About six seconds elaspe between the firing of the first and the last series of holes. Prior to the shooting of a blast, the jumbo is moved a safe distance back from the face. The rock brought down is loaded by an electric-powered Conway mucker into 36-inch gauge, 5-yard, side-dump cars. This loader slides the muck on the shovel down a channel-shaped boom to a conveyor which, in turn, fills the cars that are hauled in and out of the tunnel by gasoline- and diesel-engine-driven locomotives.

In loading the excavated material, the jumbo again comes into use, as follows: An air hoist or "cherry picker" plucks an empty from the rear of the muck train and holds it aloft while the loaded cars are pulled back out of the way. The empty is then replaced on the tracks at the head of the train and behind the loader. Two air-driven hoists mounted on the second platform of the jumbo and with their cables run over a head sheave on the top platform handle the "cherry picker." Another hoist on the upper level operates a small crane that serves to lift drill steel, drills, timbers, and other material to the various platforms.



AT THE DRILLING FACE

The breast of the tunnel at a point about 600 feet in from the western end, showing timber sets erected to hold loose ground. The men shown are, left, P. L. Graves, resident engineer for the Chesapeake & Ohio Railway, and E. E. Thompson, loader operator for the contractor.

Approximately 90,000 cubic yards of rock will be removed in driving the tunnel and used as fill near the east approach. Advance has been at the rate of about 400 feet a month, except in sections where very hard rock has been penetrated or where considerable timbering has been required. Where fractured or loose rock is encountered the walls and roof are supported by 12x12-inch timbers faced with heavy planking. There is no pressure on the timbering; it merely serves to prevent the fall of loose rock. It will be left in place and will eventually be embedded in the concrete.

A typical tunneling cycle involves four hours of drilling and shooting, five hours for muck removal, and one hour for scaling and removing loose rock. As occasion demands, hand bars, Jackhamers, stopehamers, and paving breakers are used in the latter work. Ventilating air is furnished by a gasoline-engine-driven blower with a capacity of 13,000 cfm. This unit is installed near the east portal, and the air is conveyed to a point near the heading by a 26-inch-diameter steel pipe.

The tunnel, as has already been said, is to be concrete-lined throughout, and it is estimated that about 25,000 cubic yards of concrete will be required for this purpose. The ditches and the side walls, up to a height of about 2 feet, are to be lined first. This will establish the grade and provide a support for the jumbo that will be used in placing the arch and remaining side-wall sections. The carriage will be 64 feet long and made up of four 16-foot sections that will be bolted together. Shims can be inserted between them when pouring the curved sections. Muck cars will bring in the concrete as a dry mix; a skid-mounted mixer that travels with the jumbo will finish the job; and a pneumatic "gun" will place the concrete. The floor of the tunnel is to be done last, and the ties on which the track rests are to be embedded in the concrete.

The new rail line will cross the old one near the east portal, and inasmuch as the tunnel now under construction is some 18 feet lower at that point than the original one, it will be necessary to build a temporary line swinging to the south of the existing one when the new bore is put in use. The fill at that end is of ample width to permit this. The amount of material that will have to be removed from the grade of the old line is comparatively small, and it will therefore be possible to lay the permanent line and to get it ready for service within a short time after the tunnel has been completed.

Supercharging Aircraft Engines

Part II

Paul Hoffman

MILESTONES IN SUPERCHARGER HISTORY

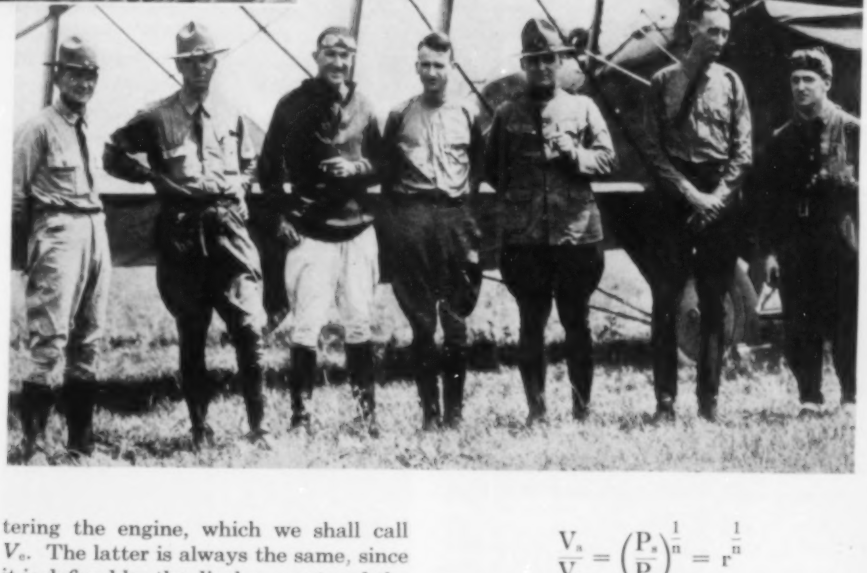
In the center of the picture directly above, Dr. Sanford A. Moss, who originated the supercharger in this country, is inspecting a modern turbosupercharger in a P-38 Lockheed fighter plane. With him are R. G. Standerwick, left, and H. W. Allen. The illustrations at the top, from left to right, show impellers for superchargers stacked high in a General Electric Company factory; Lieut. J. A. MacReady dressed for the flight on which he ascended 40,800 feet above sea level in a supercharged plane in 1921; and a diffusor, part of a present-day supercharger, framing the face of Doctor Moss. At the right, bottom, is a Lepere biplane with the crew that flew it when the supercharger was given its first flight test at McCook Field, Dayton, Ohio, in 1919. Second from the right is Maj. R. W. Schroeder, chief test pilot. His observer, Lieut. G. W. Elsey, is in the center.

IN THE first installment of this article in the May, 1943, issue, the need for altitude supercharging was traced back to a problem in combustion. It was shown how the progressive rarefaction of the air decreased its ability to burn fuel and how this caused an increasingly heavier loss of power in the engine. Supercharging was defined as the precompression of the atmospheric air before admission to the engine for the purpose of maintaining constant, sea-level density in the intake manifold and, with it, full engine power. On purely theoretical grounds it was shown what rate of supercharging would satisfy this premise, taking into account the temperature rise through compression and the effect of aftercooling. The required pressure ratio *r* of the supercharger (absolute discharge pressure over absolute intake pressure) was found to answer to the simple law

$$r = \left(\frac{d_o}{d_a}\right)^n$$

d_o being atmospheric density at sea level, d_a density at any given altitude, and n being the exponent of V in the pressure-volume relation PV^n = constant, which describes the change of state of the air by compression, with or without cooling. In Figure 4 (to which the reader may turn for reference) the required values of *r* were given for various modes of compression.

To round out this picture we want to see now what happens to the volume of the air during the process of supercharging. This means that we must find the volumetric compression ratios corresponding to the already established required pressure ratios. The volumes that interest us are those of the atmospheric air entering the supercharger, which we shall call V_a, and of the charge—cooled or not, as the case may be—en-



All photos, General Electric Company

tering the engine, which we shall call V_e. The latter is always the same, since it is defined by the displacement and the volumetric efficiency of the engine—the revolutions of the engine per minute being assumed constant throughout. If P_a and P_s again designate the absolute pressure of the atmosphere and the absolute pressure after supercharging, then it follows, from PV^n = constant, that

$$P_aV_a^n = P_sV_e^n$$

or

$$\frac{V_a}{V_e} = \left(\frac{P_s}{P_a}\right)^{\frac{1}{n}} = r^{\frac{1}{n}}$$

But, as we have already seen,

$$r = \left(\frac{d_o}{d_a}\right)^n$$

Hence, by substituting

$$\frac{V_a}{V_e} = \left(\frac{d_o}{d_a}\right)^{n \times \frac{1}{n}} = \frac{d_o}{d_a}$$

or

$$V_a = V_e\frac{d_o}{d_a}$$

In other words, the volume of atmospheric air to be taken into the supercharger is entirely independent of how efficiently it is compressed and whether it is afterwards cooled or not. It depends only on the change in density of the atmosphere; that is, on the altitude. By using the information on the relative atmospheric density given in Figure 3, we can now show how the supercharger intake volume varies with altitude (See Figure 8). This illustrates strikingly what a large air volume—relative to engine displacement—must be handled by the supercharger at stratospheric levels.

The fact that the volumetric ratio is not influenced by those circumstances that affect the pressure ratio is brought out in another way by Figure 9. It represents the theoretical pressure-volume diagrams of a supercharger at a specific altitude—20,000 feet for present purposes—for the several values of *r* which

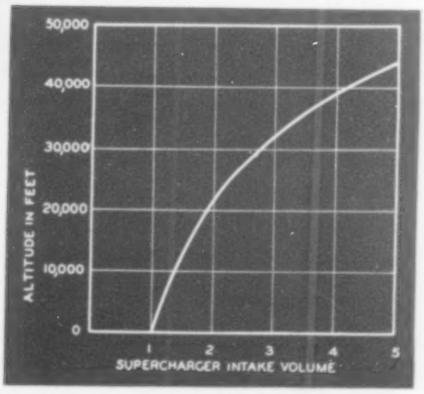


FIGURE 8

The volume of air to be handled by a supercharger increases rapidly with altitude. It varies inversely with the atmospheric density.

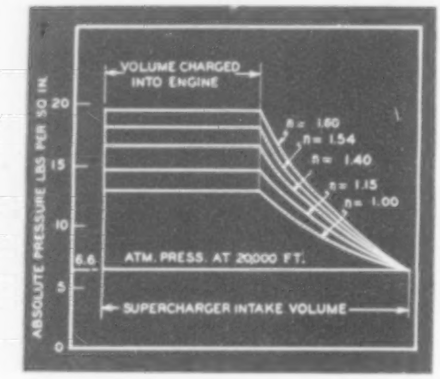


FIGURE 9

The volume of air taken into a supercharger at a given altitude is the same regardless of how efficiently it is compressed, while the pressure and the temperature of the charge may vary considerably.

appear in Figure 4. The several compression diagrams are drawn over the same intake volume as a common base. The discharge volume also is the same in all cases, although delivered at different pressures and temperatures. Of particular note is the wide variation in discharge pressure, in conformity with the different values of *n* which apply to the compression.

At this point a short digression seems to be indicated—to make comment on a certain aspect of supercharging which should not be overlooked. This is the "intake ram." Up to now, the position we have taken is that supercharging is to be accomplished entirely by a mechanically operated compressor discharging into the engine. But it is well known that the velocity of the air stream in which the plane is placed is another possible means of compressing the air taken aboard, and is actually so utilized. (Whether we consider the plane in motion and the air stationary, or vice versa, is immaterial; only the velocity of one in relation to the other is what counts, as proved by all wind-tunnel testing.) All that is necessary to this end is to introduce the air into the plane through a scoop, a sort of squat elbow facing into the wind and connected through a suitably shaped, diverging conduit with the engine manifold (or the supercharger inlet). The air, thus forced or rammed into the engine, registers a pressure rise, just as it would in going through a compressor. The intake ram may, therefore, be considered a form of supercharging, and thus the question might well be asked whether it could not replace, or to what extent supplement, mechanical supercharging. Experimentally, this question could readily be answered by measuring directly with an impact tube, projecting into the air stream, the so-called velocity head corresponding to the speed of the plane. This head would register on a manometric water or mercury column, and it could be shown how this column varies at different altitudes with the flying speed. Lacking such data, the ramming effect can be determined analytically by reference to the fundamental law of fluid flow which states that any change in kinetic energy is balanced by an equivalent change in enthropy. Applied to our case, on the extreme assumption that all the kinetic energy is converted adiabatically into pressure energy, this law furnishes the equation

$$\frac{v^2}{2g} = RT_a \frac{k}{k-1}\left(r^{\frac{k-1}{k}} - 1\right)$$

wherein v = velocity of the air current (or of the plane) in feet per second

g = acceleration of gravity, 32.2 feet per second per second

R = gas constant for air = 63.3

T_a = absolute temperature of the atmosphere

r = ratio of the absolute pressures, in compression

k = 1.4 for dry air in adiabatic compression according to Pv^k = constant.

By substituting numerical values and by transposing, this equation takes the form

$$r^{.285} = 1 + 8.5 \times 10^{-5} \times \frac{v^2}{T_a}$$

Solving for r on two assumptions for T_a (sea-level temperature of 460°F. plus 59° and stratospheric temperature of 460°F. minus 67°) yields the two r over v curves shown in Figure 10. These represent the theoretically possible compression effect by intake ram.

Figure 10 reveals a number of interesting facts. First, r is a function of the atmospheric temperature and therefore varies with the altitude, being greatest, unexpectedly perhaps, for a given speed in the stratosphere. Second, r increases very slowly at first, then more rapidly with the speed. At speeds up to about 200 mph. it is negligible. That would include most commercial, transport, and slower bombing planes. At 400 mph., which is the speed of fast pursuit ships, the effect of the intake ram becomes somewhat more impressive. And, if we could go to superspeeds of 600 mph.—the goal of some airplane designers—the ramming effect would, indeed, be appreciable. It could (of course always theoretically) boost the atmospheric pressure to 1¾ times its value in the stratosphere and to better than 1½ times at sea level. The ultimate in ramming effect would be reached at a plane speed equal to the velocity of sound—a virtually impossible condition for propeller-driven planes. This would occur at about 650 mph. (or 960 feet/second) in the stratosphere, and at about 750 mph. (or 1,100 feet/second) at sea level. These figures indicate that the intake ram is significant at high speeds only. When it is further considered that compression by intake ram certainly cannot be any too efficient, and that the theoretical values shown will nowhere near be realized in practice, it seems clear that the ramming effect, at least for all ordinary speeds, can simply be disregarded. It must be remembered, also, that even the fastest plane slows down considerably when climbing, and that is when it needs supercharging most. For our purposes we will therefore dismiss the intake ram with the statement that it exerts no appreciable corrective effect on any previously made assumptions.

The question to be considered presently is how the theoretically required, always-varying rate of supercharging might be realized in actual practice. It has already been pointed out that this could only be done by continually changing the speed of the supercharger. But just at what rate the speed would have to change depends a good deal on the kind of compressor used. A few words are therefore in order on the design, working principles, and performances of supercharging compressors.

When looking over the compressors suitable for supercharging, the most common machine, the reciprocating or piston type, must be dismissed for airplane service because it its too slow, too heavy, and too bulky. Only a machine capable of high speed will answer, which makes the centrifugal compressor the best choice. Another type that has been used for supercharging, although it is not in the same class in regard to speed, is the positive-displacement rotary compressor. Both the centrifugal and the rotary have one advantage in common over the piston type; they need no valves and have no reciprocating

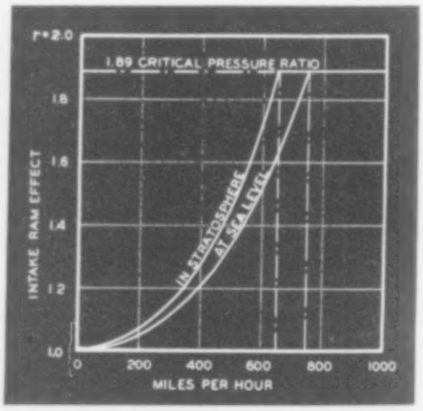


FIGURE 10

Here is shown the theoretical pressure ratio produced by the intake ram. This is a form of supercharging that makes use of the speed of the plane to force the air into the intake manifold. It becomes significant only at tremendous speeds—those of the planes of the future.

parts. Otherwise they are quite dissimilar.

Let us look first at the rotary compressor. It is akin to the reciprocating compressor in that it is a positive-displacement machine the working principle of which is as follows: With each revolution, the apparatus takes in a certain volume of air. This is entrapped, or sealed in, by appropriate moving members and is then compressed and forced out. The body of air "displaced" from the atmosphere into the discharge pipe is in fact somewhat less than the geometrical displacement because of slippage, or leakage, and because of the reexpansion of some of the air compressed into certain required clearance spaces. This difference is expressed by the volumetric efficiency of the machine. However, for the sake of simplicity, we will speak of the delivered volume—measured at intake pressure—as the displacement.

The effect of the piston displacement in the cylinder of a reciprocating compressor is obtained in different ways in the rotary type of machine. The air may be displaced by two intermeshing gears, or similar members, revolving in opposite directions in a closely fitting housing; or the air may be carried forward by vanes sliding in and out of a rotor running eccentrically in a cylindrical casing. In fact, innumerable designs have been proposed, and some of them are in use. The feature common to them all is that they deliver a fixed volume of air per revolution; that is, their capacity, or the volume delivered per minute, is proportional to the number of turns per minute. (Actually, a slight correction is necessary because the volumetric efficiency is affected by speed and pressure ratio, but this is disregarded here.) If, then, the capacity is expected to vary according to a certain law, this can be readily accomplished by varying the number of revolutions per minute in accordance with that law. And, since we have already found how capacity should vary with altitude in supercharging work, we can put down immediately the following rule for varying the supercharger speed

$$\frac{rpm_a}{rpm_o} = \frac{V_a}{V_e} = \frac{d_o}{d_a}$$

or

$$rpm_a = rpm_o \frac{d_o}{d_a}$$

which simply says that the speed should vary inversely with the atmospheric density.

The assumption here is that the speed of the supercharger, rpm_o, at sea level is that required to displace, without compression, a volume V_e equal to the engine displacement. In other words, the supercharger is supposed to be running at all times, even at sea level when this is seemingly unnecessary. The change in speed from sea level to an altitude of 40,000 feet would obviously follow the same curve as that given in Figure 8 for the change in volume. Reading from this curve, we can see that at 20,000 feet, for instance, the supercharger would have to run nearly twice as fast as at sea level, and at 40,000 feet more than four times as fast.

If we turn now to the centrifugal compressor we find that the relations between speed and either pressure or compression ratio are considerably more involved. In this case there is no fixed displacement of a definite volume per revolution but, instead, a continuous flow through open passages that is induced by the rapid rotation of a paddle-wheel type of impeller. The rate of flow depends on the speed and, naturally, also on the dimensions of the impeller. Besides, it adjusts itself in a degree to the resistance to be overcome. As to the pressure, this is a somewhat complex function of the peripheral speed of the impeller, of the angle at which its blades are set, and of the design of the air passages that follow the impeller and in which acquired velocity is converted into pressure. Performance is predictable only by the use of empirical factors and must be subject to verification by test. An interesting feature is that the pressure generated at a given speed changes with the volume, dropping off as the volume increases until it is eventually reduced to zero, the efficiency, in general, following the same course. Another peculiarity is that operation below a certain critical volume has a tendency to be unstable, a condition that is often referred to as pumping.

The usual procedure in designing a centrifugal compressor for certain predetermined operating conditions is to fall back upon the known performances of other comparable compressors. When a machine is tested, the results are conventionally laid down in a graphic plot, with the pressures, or pressure ratios, as ordinates and the intake volumes as abscissae. Points of constant speed are

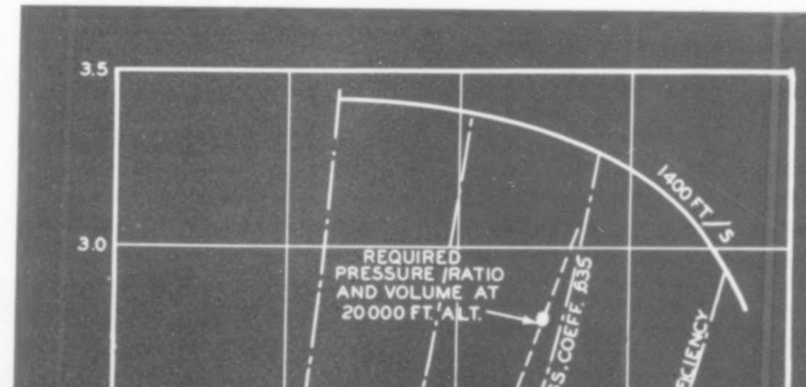


FIGURE 11

So-called characteristic curves of a typical centrifugal compressor of a suitable size for supercharging.

joined by curves, the so-called pressure characteristics of this particular compressor. A typical graph of the performance of a single-stage, supercharging centrifugal compressor is submitted in Figure 11. Here pressure ratios, and not discharge pressures, are plotted over intake volumes, which is more convenient when the intake pressure is variable. For a purpose that will become clear later on, the characteristic curves are drawn for given peripheral speeds of the impeller and not for the number of revolutions per minute. It will also be seen that the pressure-ratio curves are supplemented by a series of parabolalike curves drawn from the origin of the system of coördinates, these representing constant volume/speed curves. For all points on one of these curves, the entrance and exit conditions in and out of the impeller, or, geometrically speaking, the impeller-velocity triangles, are similar; hence, these parabolas are also constant efficiency curves. Another interesting property of theirs is that, from one point to another on any one curve, the pressure ratio and the speed do change according to the following, definite relation

$$\frac{r_2^{\frac{k-1}{k}} - 1}{r_1^{\frac{k-1}{k}} - 1} = \left(\frac{n_2}{n_1}\right)^2$$

which holds true so long as the intake temperature remains constant. The expression

$$r^{\frac{k-1}{k}} - 1$$

is basic in many compressor calculations. It is often replaced by the symbol *X*, values for which, in function of *r*, are listed in various reference books (among others, in *Compressed Air Data*, 1941, pages 89 and 90). For instance, *X* enters into the formula for mean effective pressure in adiabatic compression, commonly used in piston-compressor computations, which is

$$\text{mep} = \frac{k}{k-1} X$$

And this leads to a somewhat odd interpretation of the preceding equation; that is, in a centrifugal compressor a certain function of the pressure ratio, which is equivalent to the mean effective pressure in a piston-type compressor but has no concrete meaning in a centrifugal machine, varies with the square of the speed so long as V/n remains constant. (Parenthetically, warning is given of the fact that there is a belief, often expressed, that it is the discharge pressure which varies in this way.) If the intake temperature is variable this modifies our equation to

$$\frac{X_2}{X_1}\frac{T_2}{T_1} = \left(\frac{n_2}{n_1}\right)^2$$

from which

$$X_2 = X_1 \frac{T_1}{T_2}\left(\frac{n_2}{n_1}\right)^2$$

and

$$n_2 = n_1 \left(\frac{X_2}{X_1}\right)^{\frac{1}{2}} \left(\frac{T_2}{T_1}\right)^{\frac{1}{2}}$$

These formulas furnish a ready means of determining the speed for any desired pressure ratio, or vice versa, provided a single pressure-ratio characteristic is known, and therefore make it possible to establish the whole network of characteristics from test data obtained at only one speed. However, in extending these curves upward, a limit is set by the maximum speed at which the compressor may be safely operated. As will be noticed in Figure 11, the highest pressure-ratio characteristic shown is for a 1,400 feet/second rim speed. This is very nearly top speed for a supercharger impeller of the best design and most suitable material. Beyond it, centrifugal stresses become quickly unmanageable, going up as they do with the square of the speed.

But there is another reason which prompts restraint. When the rim speed of the impeller exceeds the acoustic velocity of the air (which will be around 1,100 to 1,150 feet/second for the compression temperature to be expected at that point) the performance gradually begins to deteriorate. Pressure does not continue to gain with speed, as expected; efficiency falls off; and the stable operating range of the compressor narrows down more and more. (In Figure 11 this sort of deterioration has not been indicated, and the theoretically expected pressure characteristics for 1,200 and 1,400 feet/second are consequently somewhat misleading.) There is little point, therefore, in increasing the risks of mechanical operation for the sake of fast-diminishing returns in performance. The practically realized pressure ratio in single-stage, centrifugal superchargers probably does not exceed a value of about 2.5 to 3.0. This evidently puts a limit on the altitude which a plane so supercharged can negotiate. The remedy consists of 2-stage compression which is possible with one and the same supercharger, or in putting two separate superchargers in series. It will be seen, later, that this opens the way to almost unlimited high-altitude flying

Returning now to the desired speed-to-altitude relation for centrifugal compressors, it has become clear that there is no generally applicable analytical answer to this problem. Each different centrifugal compressor has somewhat different performance characteristics, although they are the same for all geometrically similar machines. Each, therefore, reacts somewhat differently to speed changes. The compressor having the characteristics assumed in Figure 11 would, for instance, have to change speed with altitude according to the

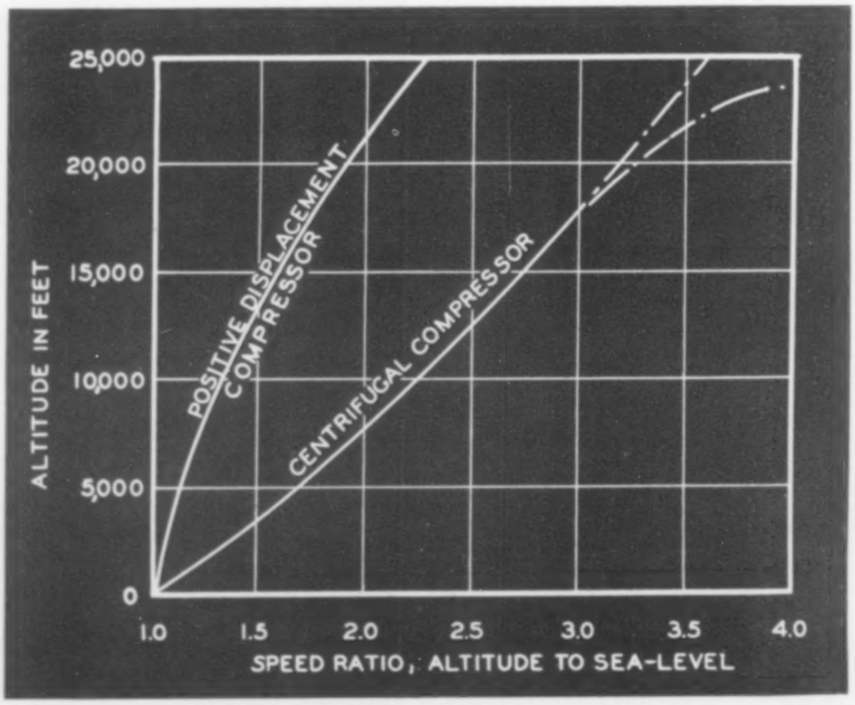


FIGURE 12

The rate of speed increase of a supercharger theoretically required with rising altitude to maintain constant manifold pressure. The right-hand curve, while typical of the performance of centrifugal compressors, applies only to a machine having the particular characteristics shown in Figure 11. The break in this curve indicates the disturbance that is known to take place when the peripheral speed of the impeller exceeds the speed of sound.

curve shown in Figure 12. This is arrived at by a combination of the pressure ratio to altitude relations given in Figure 4 and the information furnished in Figure 11. By comparison with the corresponding curve for a positive-displacement compressor, it is made apparent in Figure 12 that the change in rate of speed with increasing altitude would have to be quite different for the two types of compressors

Supposing, now, that the speed to altitude relation of a given supercharger, required to maintain constant manifold pressure in the engine, were correctly established by means indicated here. What has been gained? Two pertinent questions may be asked from a practical viewpoint: First, could the proper speed be mechanically realized, and, second, is it actually of great importance to do so? The answers are somewhat disappointing to the theorist, as we shall see presently.

To obtain the necessary, complete variability in the supercharger drive would call either for a multiplicity of gear ratios or for interposing some flexible element such as a hydraulic coupling in the gear train. The first is well-nigh impossible, but the latter has actually been applied to some German superchargers, although it appears none too easy. After providing the means for speed variation, the mechanical control of those means has to be worked out, for it is clear that the repeated, manual readjustment of the speed ratio, say on the basis of altimeter readings, would impose a burdensome task on the pilot. Some automatic device reacting to the change in atmospheric density would be required—a pretty tricky affair, inasmuch as density is a compound of pressure and temperature and not too easily measured directly. Anyway, the result could be accomplished only at the cost of some complicated auxiliary gadgets, and a plane is already full of them!

Actual practice has, therefore, reasonably given up all attempts to find the ideal solution. Proceeding on the basis that absence from excessive complications is of prime importance, aircraft designers have generally been satisfied with direct gear drive, or they have gone to no more than two separate speed ratios. The single-gear ratio means, of course, that the supercharger runs at top speed all the time, or that there is only one other choice, namely, having it unclutched. Necessarily, then, correct supercharging as defined here obtains at but one specific altitude. Above that altitude supercharging is deficient, below it, it becomes excessive. The former can't be helped, but the latter is obviated by blowing off the surplus air, which represents a certain loss in power that is unavoidable but not too serious. Also, this arrangement provides "satisfactory" booster supercharging at the take-off when momentary maximum power is required. All that is needed is to admit the full, compressed charge to the engine and to open the fuel throttle wide.

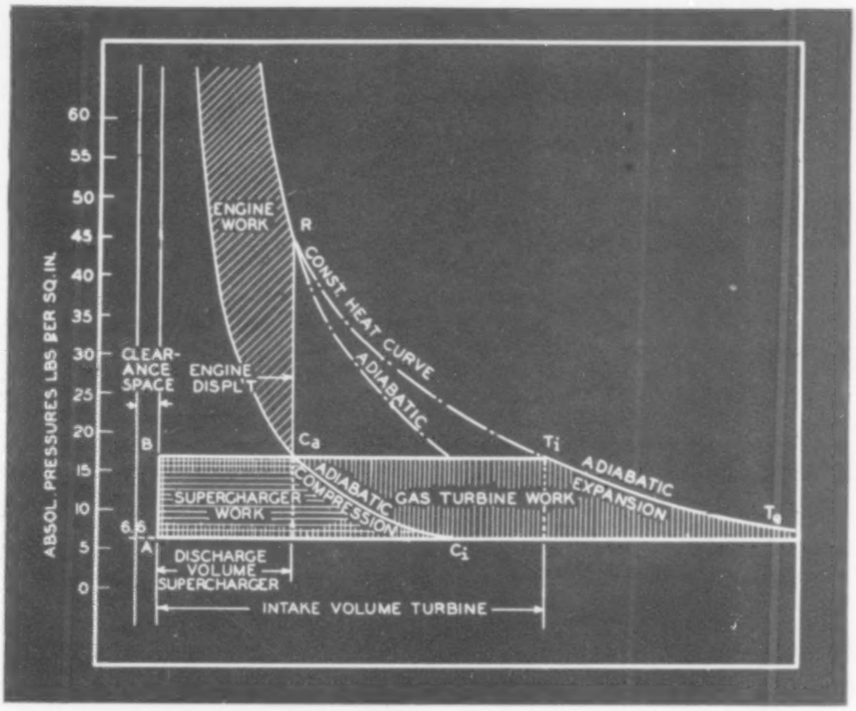


FIGURE 13

A theoretical work diagram of a turbosupercharger at 20,000 feet. This shows that the available energy in the engine exhaust gases is more than sufficient to furnish the necessary power in the turbine to operate the supercharger.

We have kept for the last the most interesting of the superchargers, so far as method of driving is concerned. This is the so-called turbosupercharger, which not only is the ideal solution of the motive-power problem but possesses many other advantages. The turbosupercharger is a self-contained unit, consisting of a centrifugal compressor driven by a gas turbine. The single turbine wheel and the compressor impeller are mounted on a common shaft but are separately housed, the whole forming a compact assembly. The turbine utilizes the exhaust gases of the engine which, released at considerable pressure and high temperature, are a potential source of energy that ordinarily goes to waste. The beauty of this arrangement is that, as altitude increases and the compressor is called upon to do more work, a greater amount of exhaust-gas energy becomes available because of decreasing back pressure. To a large extent, therefore, the turbosupercharger adjusts itself automatically to the demands made upon it.

The main facts contributing to the balance of needed and supplied power may be more fully appreciated by reference to Figure 13. This is a combined *p-v* diagram of engine, supercharger, and turbine, drawn freely for conditions at an altitude of 20,000 feet. The gases released from the engine cylinder at point *R* as the piston ends its expansion stroke may be considered to be throttled down to the supercharging pressure—intake and discharge-manifold pressures being alike—without doing any work or losing heat. Point T_i indicates the condition at the turbine inlet. Expansion in the turbine takes place from T_i to T_e, the theoretical expansion work being represented by the area ABT_iT_e. On the other hand, the compression work in the supercharger is represented by the area ABC_dC_i. If compression and expansion took place adiabatically, the two work areas would be measured by the absolute temperatures at T_i and C_d. For our assumptions—that is, 20,000 feet altitude—the compression temperature at C_d would be about 120°F. while the turbine-inlet temperature might be in the neighborhood of 1,400°. Corresponding absolute temperatures would then be 580° and 1,860°, their ratio being about 0.31. Hence, the over-all efficiency of the turbosupercharger need be no better than 31 per cent (split, let us say, into 60 per cent compressor efficiency and 52 per cent turbine efficiency) to satisfy the power-balance requirement. Better efficiency would result in surplus power, and this is mostly available, except at lower altitudes. The usual way to dispose of the surplus is to by-pass part of the exhaust gases through a dump valve controlled, for instance, by the charging pressure.

Clearly, then, there is no special problem of speed adjustment or speed control in the turbosupercharger. One of its other advantages is this: Because it is a separate entity, connected to the engine only through piping, there is more freedom in locating it conveniently, and cooling after compression can be applied much more easily than in a geared supercharger which must be practically built into the engine housing. As seen before, aftercooling means a substantial reduction in the required pressure ratio for a given altitude, or, for the maximum obtainable pressure ratio, it means an appreciable gain in the critical altitude of the plane—that level at which supercharging begins to fall below full requirements and engine horsepower starts on its steady decline.

Even without the benefit of aftercooling, the turbosupercharger still has the edge on the geared supercharger in regard to this critical altitude. Both are equally limited, it is true, in the matter of maximum impeller-rim speed which mechanical strength permits, hence in attainable pressure ratio. But when running at top speed, the geared supercharger absorbs a measurable percentage of the engine horsepower, thus reducing the power available for the propeller, whereas the turbosupercharger leaves the engine power unimpaired. A higher critical altitude is the result.

The incidental fuel saving realized by the use of a turbosupercharger is merely mentioned here without elaborating on its effect on the flying radius of the plane. This is not the place, either, to go into details as to the construction of the turbosupercharger, interesting as the subject may be. These matters, as well as the fascinating story of the evolution of this apparatus, have been well covered in a recent book, *Supercharging for Aviation*, by Dr. S. A. Moss, originator of the turbosupercharger in this country.

It remains now only to present some general conclusions on the effect of supercharging in its various forms not only on the engine horsepower but also on the performance of a plane. This has been done graphically in Figure 14. As a yardstick of plane performance, the ceiling of the plane was selected—the same plane fitted with the same engine serving, of course, in all cases. It was assumed that the ceiling would be reached—that is, that the plane would lose its capacity to climb any higher—when the engine power dropped to one-third of its full rating, a supposition supported by published data on recent aircraft. It was further taken, for the sake of simplification, that the supercharger was a centrifugal compressor and that its attainable pressure ratio would have a value of not more than 2.5, to be on the safe side. The net engine horsepower was assumed to decline from the critical altitude to the ceiling at the same rate as in the unsupercharged engine for the corresponding altitude range.

Reading, then, from Figure 14, we find the following: The ceiling for the plane powered with the unsupercharged engine is 23,500 feet. The application of a supercharger, geared to or otherwise driven from the engine, raises the ceiling to about 33,500 feet. A turbosupercharger jumps this another 2,000 feet, approximately to 35,500 feet. A bigger upward step results from cooling the air after supercharging, which gives the plane a ceiling of some 43,000 feet. The real advance into the upper atmosphere comes, however, with 2-stage supercharging. It is assumed here that this is effected by a geared supercharger acting as the first compression stage, and by a turbosupercharger acting as the second stage, with intercooling of the air between the two. A ceiling of more than 60,000 feet is indicated with this combination, which is probably high enough for all practical needs today.

In the picture that has been presented, no particular claim is made as to the accuracy of the absolute values, as these must change with the underlying and more or less arbitrary assumptions. It gives, however, a clear idea of the relative merits of the different methods of supercharging discussed. Expressing our findings in broad terms, we see now that single-stage supercharging is too limited in its scope, although it may be considerably enhanced by aftercooling, and that extreme altitudes can be reached only by 2-stage compression, supplemented by cooling. In addition, the turbosupercharger claims for superiority seem to be well substantiated.

The foregoing conclusions are, in general, borne out by actual experience. Thus, theory has merely confirmed practical results; but it is hoped that it has, besides, performed the function of clarifying and giving a better appreciation of the main facts of supercharging.

This is the concluding installment of Paul Hoffman's article on "Supercharging Aircraft Engines." Part I appeared in the May issue.

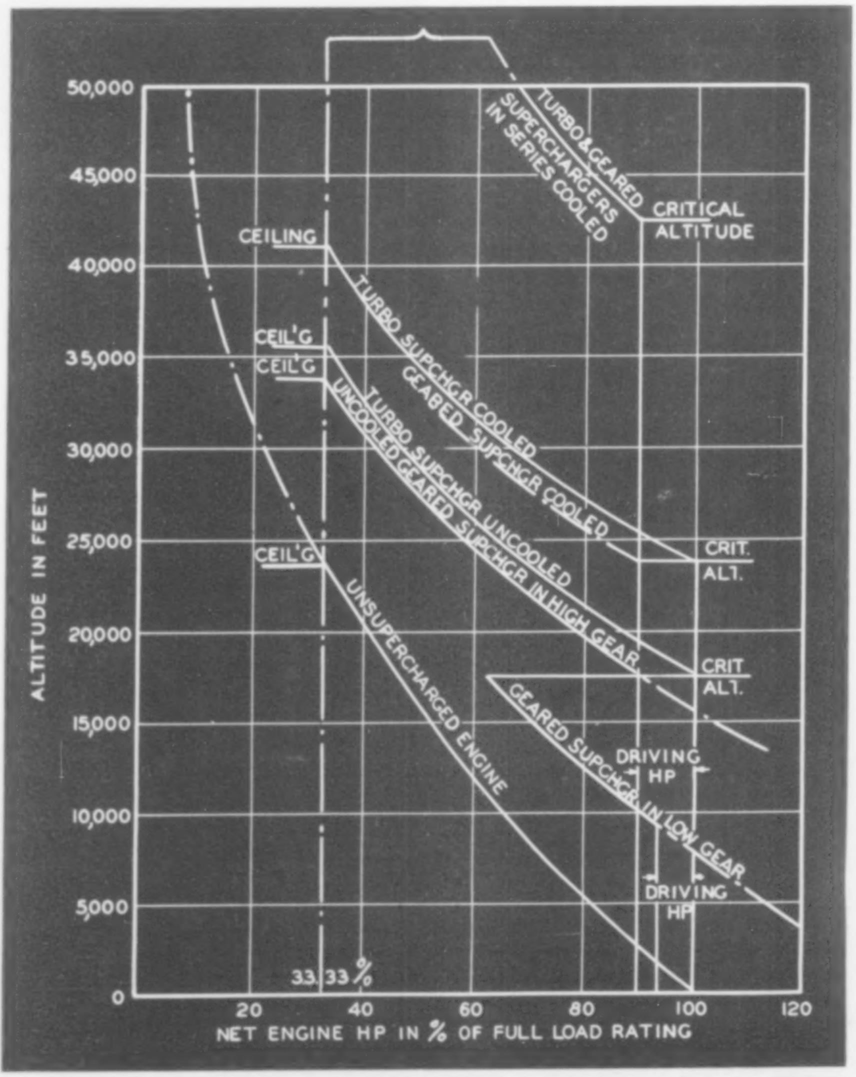
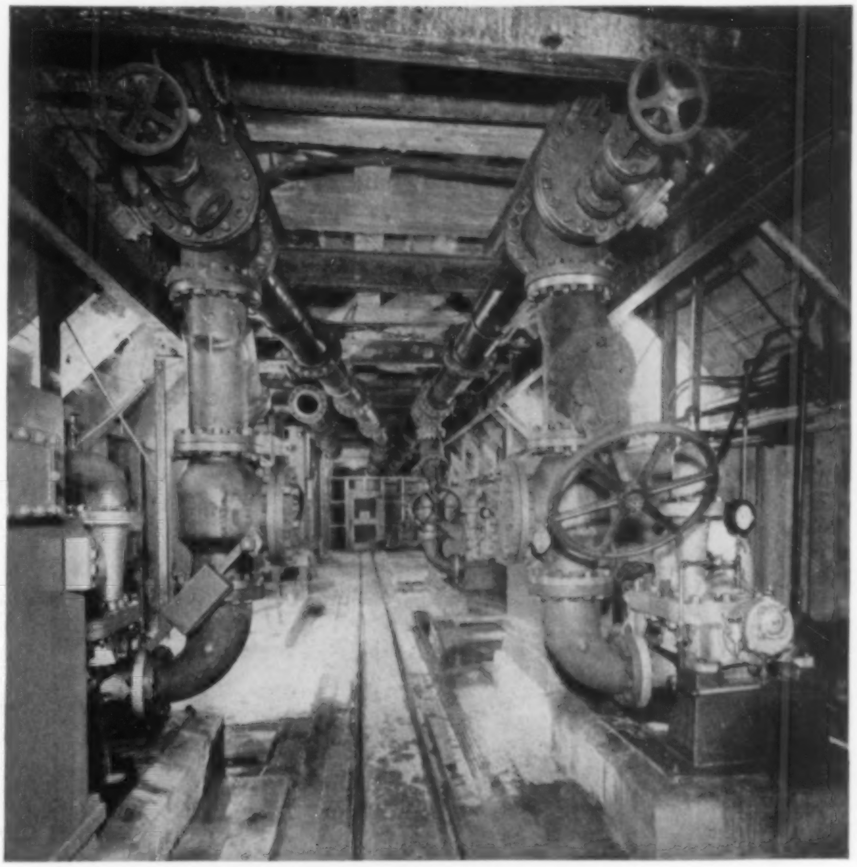


FIGURE 14

Showing the over-all effect of various methods of supercharging on the critical altitude and ceiling of a plane.

Central Pump Station Serves Butte Mines

Marcus McCanna[*]



UNDERGROUND PUMP STATION

A lengthwise view, looking northward toward the shaft through which water is pumped to the surface in four lifts. Three pumps are in service. A fourth is being added, which will give the station a capacity of 6,000 gpm., and room has been provided for two more units. The discharge pipes are arranged overhead to facilitate cleaning them out and are suspended from a self-supporting steel structure that also carries a continuous crawl beam mounting a 5-ton, geared-trolley chain hoist that can be moved directly over any pumping unit.

AS A RESULT of the continuation of values with increasing depth and a progressive lowering of the mining horizon, many mines of the Anaconda Copper Mining Company in the Butte district became far deeper than the main drainage crosscuts which carried the mine water to the two main pumping shafts, namely, the High Ore and the Leonard. Inasmuch as the water horizon moves down with the mining operations, it was necessary to maintain pumping stations at the various mines in order to raise the water to the 2800-foot level, where it drained by gravity to the large centralized pump stations located at the aforementioned shafts.

After careful consideration and study it was decided to establish the 3800 as the drainage level; to drive three long crosscuts at gravity grade from the High Ore, the longest to be 3,300 feet in extent; to transmit the water through these crosscuts, supplemented by branching waterways to the more remote mines; and to concentrate the pumping load at one centralized plant. This was done for the twofold purpose of eliminating the independent pumping plants, including the Leonard, thereby reducing pumping costs and effectively prospecting a considerable area of virgin territory for mineral content by means of the long crosscuts.

The new pump station with which this article is concerned was established in the High Ore Mine at an elevation 23 feet lower than the 3800 drainage level. Owing to the fact that the waters were to approach from three directions, as well as for flexibility of manipulation, the storage reservoir was cut in the form of a "ring" around the shaft. The pump station proper, which is 118 feet in length, 12 feet in height, and narrows in width from 28 to 20 feet, is within this ring. At the points where the units are located along both sides of the station, a crosscut for each was driven normal to the station to accommodate a suction pipe from an individual dam.

At each of the three places where the drainage crosscuts pass over the storage ring a raise was driven from the ring and a dam placed at the bottom of it to divert the descending water to one or the other side—in effect, to divide the storage ring roughly into three parts. In addition, suction dams on either side of the station are joined together and connected to two segments of the ring. These dams are formed so that they can be provided with slat screens or removable boards for barricading the water from any direction. Obviously, this layout makes it possible to isolate any third of the storage ring for the decanting of water and the removal of mud without interrupting the operation of any pump. Also, each ring segment is connected with the station proper by a crosscut that is plugged by a clean-out bulkhead having removable doors for the access of sludge cars. Experience had shown that the mud, which is composed of sediment and cuttings consolidated by an ocherous precipitate, could be successfully removed from storage areas only by excavating.

The ring and connecting crosscuts were driven on the same datum as the pump station, and being 10 feet wide and 16 feet high, the cross section called for suction dams 17 feet in height. The bottom 6 feet of the storage area is maintained as a still-water zone for the settling of mud, the next 2 feet serves as the operating zone, and the upper 8 feet constitutes the available volume for emergency storage. This height of operating zone provides a positive head on the pumps, thus permitting the use of high-efficiency centrifugals for the job. The

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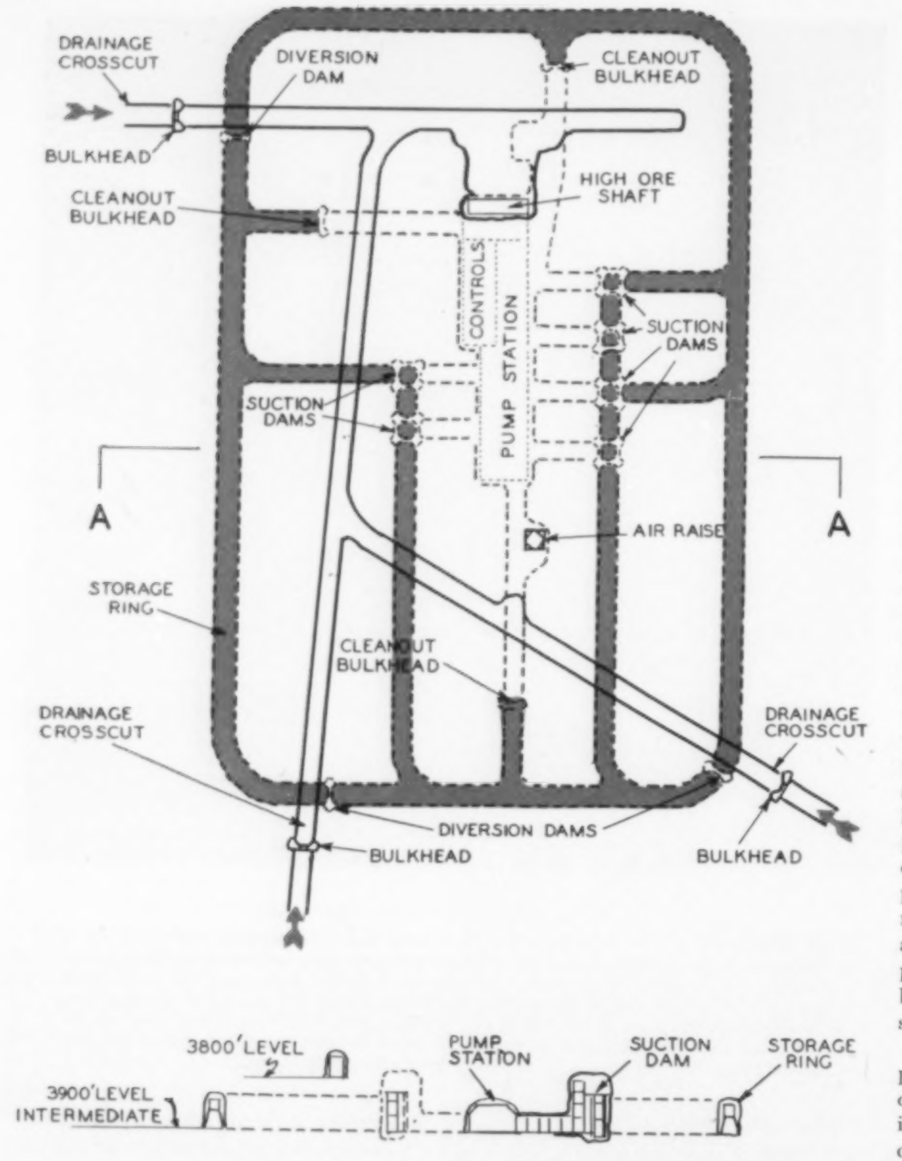
[*] Engineer, Mechanical Department, Anaconda Copper Mining Company.



SECTION A-A

LAYOUT OF DRAINAGE CENTER

Three crosscuts, the longest of which is 3,300 feet in extent, deliver water by gravity from other mines to this area, which is adjacent to the High Ore shaft. They are on the 3800 level and are indicated by solid lines. Each crosscut is connected by a raise with the "ring" reservoir, excavated from rock on the 3900 intermediate level. The dotted lines show this ring, with its interconnecting passages and suction dams through which impounded water is directed to the pump station and thence elevated by centrifugal units through pipe lines leading up the shaft. This central drainage basin collects and handles the water from the lower levels of most of the mines in Butte.

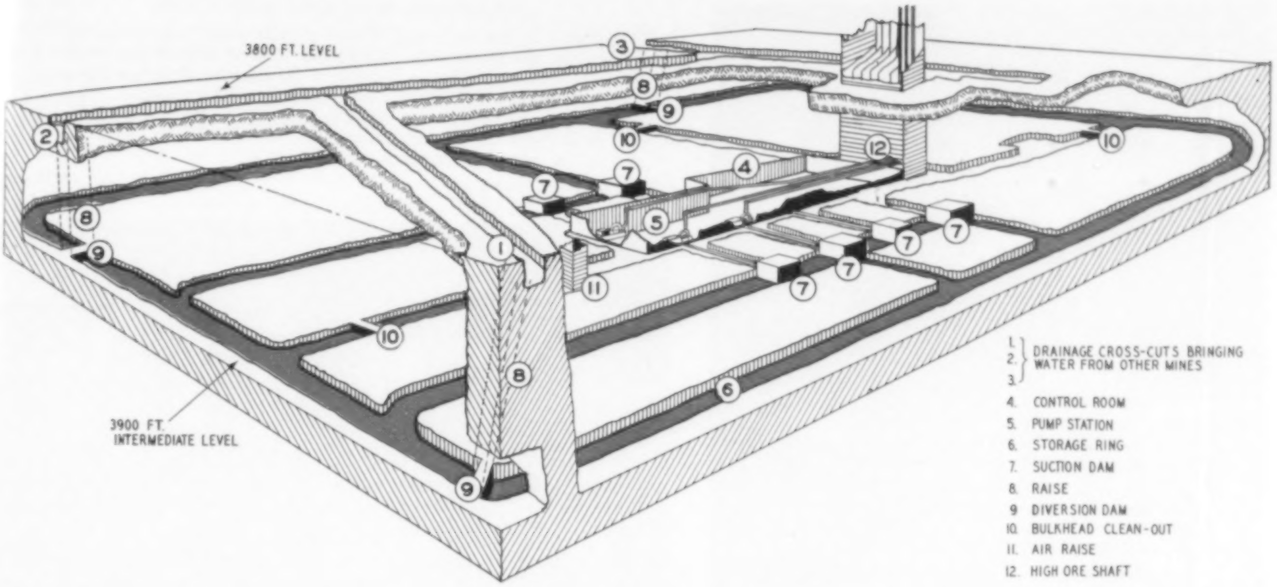
1700 lineal feet of storage has an apparent capacity of approximately 2,000,000 gallons of water. However, the actual volume available for emergency storage, as previously shown, is from one-half to five-eighths of this amount, depending upon whether the emergency arises when the water level is at the top or at the bottom of the operating zone. More will be said about emergency storage later in this article.

The pumps selected for the work were manufactured by the Cameron Pump Division of Ingersoll-Rand Company and are of the No. 6 RT 4-stage centrifugal type having a rated capacity of 1,500 gpm. against the required head when operating at 3,550 rpm. Because of the extremely corrosive character of the water, all pump parts in contact with water are made of a special alloy. Pump glands are lubricated with fresh water at suitable pressure. Each pump is provided with an individual suction pipe and discharge column. Check and shut-off valves are of stainless steel, miscellaneous fittings are of Anaconda's own special phosphor-bronze, and column pipes are of steel lined with pure lead. Each pump is mounted on a common base with and directly connected to a 700-hp., 3,600-rpm., 2,200-volt, totally enclosed air-cooled motor. The motor coolers are provided with heat interchangers through which fresh water is pumped by I-R Motorpumps. Two 400,000-circular-mil cables, plus a spare, are installed in the shaft to carry the power load and are landed in truck-type switchgear. These, with automatic reduced-voltage starting compensators and other necessary equipment, are grouped in a large control room situated at the wider section of the station and from which cables are carried overhead and dropped to the motors.

The pumping units are arranged along both sides of the arched station with an aisle between. Horizontal discharge pipes leading from the pumps to the shaft columns are carried overhead and above the aisle for ease of removal to clean out ocher. They are suspended from a self-supporting steel structure, together with a continuous crawl beam with a 5-ton, geared-trolley chain hoist that moves along the center line of all the pumps. This arrangement relieves the station timbers of the weight of the heavy pipe and lifting loads. Three pumps are now in operation and a fourth one will be set up shortly, giving a capacity of 6,000 gpm. Provision has been made for the future installation of two additional units. Safety features for the protection of the equipment include bearing-temperature relays and float switches for automatic cutout.

The three drainage crosscuts are provided with emergency bulkheads just outside of the storage-ring area. Those in the two longer crosscuts, which also carry the bulk of the water, are equipped with motor-operated valves that are controlled at the pump station and use direct current supplied by a set of Edison storage batteries with an automatic charger. Alternate station lights likewise use direct current from this source, thus keeping the batteries in a constant state of charging and discharging. In the event of complete power failure, the station would still have lights and the operator would immediately close the valves by remote control, causing the water to back up in the long crosscuts and allowing the water from the lesser source to build up in the storage ring. This situation could be maintained for a considerable period of time. It is also the intention to take advantage of this feature in dispatching power loads by removing pumps from operation during peak periods aggravated by high hoisting and air loads.

Excavating for the pump station and drainage crosscuts was a considerable mining operation in itself. The shaft was sunk from the 3400 to the 3900 level. Skips were again placed in use for hoist-

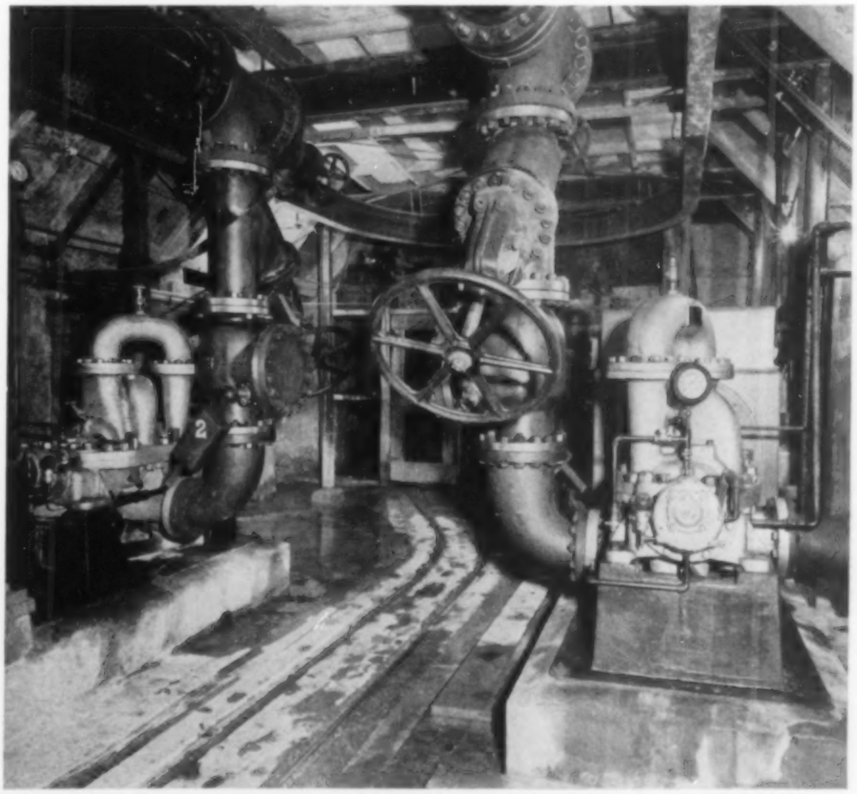


PERSPECTIVE OF STATION
This artist's drawing visualizes the underground pump station and the interconnecting network of gathering waterways and discharge lines.

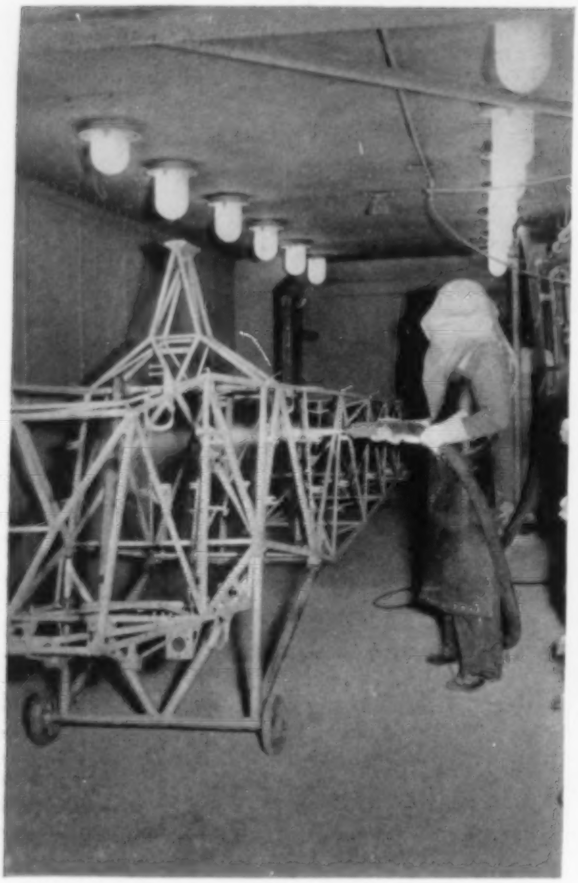
ing rock, and a skip pocket was cut at the 3900 intermediate, with transfer from the 3800. One of the first steps was the driving of an octagonal air raise for a vertical distance of 411 feet in order to connect with established airways and to provide ventilation for the ensuing mining operations, as well as to serve the same purpose for the completed station. Air coolers were installed, and booster fans were of course required to carry air to the working faces. A temporary centrifugal pump was set up on the 3900 intermediate and a sump pump on the 3900 to handle water that collected in the new openings. Ingersoll-Rand drilling machines and Jackbits were used for the work, and mucking machines, cherry pickers, storage-battery locomotives, and large-capacity Granby-type cars were employed for loading and transporting the rock. Several breasts were advanced simultaneously. Owing to the character of the ground it was necessary to timber the station and storage ring, as well as most of the drainage crosscuts. The storage ring was cut in two operations; that is, the sill set first and the remainder later. Dams, bulkheads, foundations, and floors were formed of reinforced concrete and called for the use of a large quantity of material. This was mixed on the surface and caged to the sites. A deterrent was added to the mix to postpone the initial set.

Pumping to the surface is accomplished in four lifts at the High Ore, which no longer operates as a mining shaft but is maintained solely for pumping purposes. Stations on the 2800, 2200, and 1200 levels are equipped with sixteen Anaconda Quintuplex plunger pumps. These have been supplemented in recent years by five I-R No. 3 AET centrifugals and will soon have their combined capacity increased to match that of the 3900 by the installation of four No. 6 RT 4-stage and two No. 3 AET centrifugals. It should be stated that several of the shafts in the Butte district extend even below the newly established drainage level and that it is still necessary to maintain sump pumps and other small units to raise some water to the gravity level.

The extensive mining, mechanical, electrical, and pumping experience of many men was utilized to the fullest extent in laying out and designing the drainage system, which shows every promise of being a highly satisfactory installation.



CLOSE VIEW OF PUMPS
Two of the three Ingersoll-Rand centrifugal units that handle the present pumping load. Each is a 4-stage unit with a capacity of 1,500 gpm. against the required head and is driven by a 700-hp. motor mounted on the same base. The picture shows the south end of the pump station.



BLASTING MACHINE AND ROOM

Below is the twin unit which cleans eight trench-mortar shells simultaneously in half the time in which the work was formerly done. A total of 16 tons of abrasive flows through the unit hourly and is reclaimed for reuse. The other picture shows a modern blasting room of the down-draft type that is spacious enough to accommodate an entire airplane fuselage frame.

Abrasive Blasts Save Time on Production Front

WAR production is finding many new applications for sand-, grit-, and shot-blasting with the aid of compressed air. One of the most unusual of these is the shot-peening of airplane and automotive engine parts and other pieces of machinery to relieve fatigue-inducing stresses that cause failure. This work is done by projecting 1/16-grain steel shot with air at from 80 to 100 pounds pressure against the surfaces of the metal, which has previously been heat-treated. Among the machine parts that are given such treatment are automobile- and airplane-engine valve springs, with the result that their service life, according to one manufacturer, is increased approximately eight times. Automobile clutch disks are similarly subjected to shot-peening, and flexing tests have shown that they possess far greater endurance than the ordinary type.

In making a survey of the many uses to which blast-cleaning is put in industrial establishments, the Compressed Air Institute has found that many factories consider this method of cleaning metal parts, for example, more economical and easier to control than pickling. Fumes from the baths are hard to confine so that they will not cause damage to roof structures and other parts of buildings through corrosion. On the other hand, in the case of blast-cleaning, the shot, grit, or sand is easily recovered in collectors that prevent their scattering and permit repeated reuse.

Today, the choice of an abrasive is not haphazard; it is selected with care for the job to be done. Steel grit is generally preferred for cleaning iron and steel, while sand and Carborundum grit are generally utilized for nonferrous metals. But steel grit has its advantages. As compared with sand, it can be applied with from 10 to 12 per cent less compressed air, and, besides, sand wears out blasting nozzles much faster than do the steel particles.

In descaling forgings by blasting, it has been the practice to remove first the forging scale and then the annealing scale. Now time is saved by eliminating one of these operations—by descaling only once after annealing, which tends to soften the scale and makes it easier to blast away. Today, forgings are being made to close tolerances so there is little metal to be cut away after blasting. This applies especially to shells, and helps to speed output.

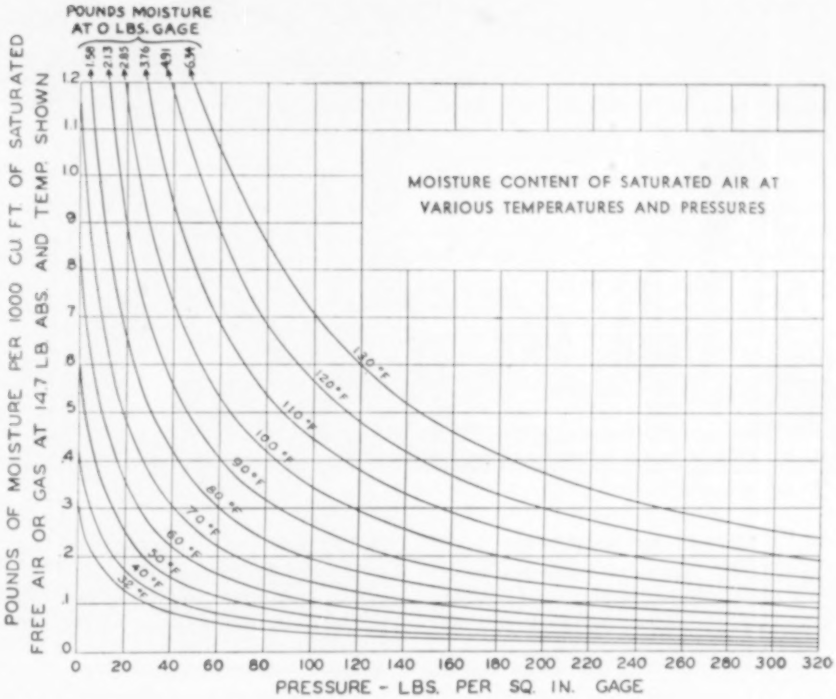
Among the shell-cleaning equipment of this type in use, one of the best was found to be a machine that holds a series of shells in the inverted position. Each is caused to rotate, and, as it turns, the nozzle projecting into it oscillates and throws the abrasive upward, thus covering the entire inner surface. The abrasive is discharged by gravity. The set-up permits rapid production—in fact, in consequence of improved methods of heat-treating and blasting, it is now possible in some cases to handle twice as many shells in a given period as formerly.

There is also a twin unit that cleans eight shells at a time. It is operated by two men, each of whom places shells over his group of four nozzles, opens the air valve, closes it again when blasting is completed, and removes the finished work. Each of the ⅜-inch-diameter nozzles uses air at the rate of 200 cfm. which, in a typical set-up, is supplied by a 2-stage compressor. The dust is carried away by blower air, which passes through a collector where it filters through a cloth screen and is conducted back into the blasting room. The abrasive, together with the scale and other foreign matter, goes into a separator, from which so much of it as is fit for reuse is returned to the blasting cabinet 98 per cent clean. The system handles a total of 32,000 pounds of abrasive an hour, and every three hours a 100-pound sack is poured into the hopper to make up for the amount expended.

The Compressed Air Institute emphasizes the need of keeping the blasting material and the air dry for maximum effectiveness. Some factories try to get by with water traps to collect the moisture in the air, but the results are not uniformly successful. Many are provided with aftercoolers, which insure the removal of most of the moisture. In one plant visited, the air is heated in a large tunnel underneath the blasting building. This is quite satisfactory; but the same cannot be said for all the heating methods that are used to prevent the condensation of water vapor carried in the air. An ingenious device, observed in an electrical-equipment manufacturing plant, consisted of a combination electric heater and charcoal absorption tower. However, its operation is not economical. Preheating apparatus, if they are to be used to best advantage, should be placed as close as possible to the blasting stations so that the evaporated moisture will not have a chance to condense.

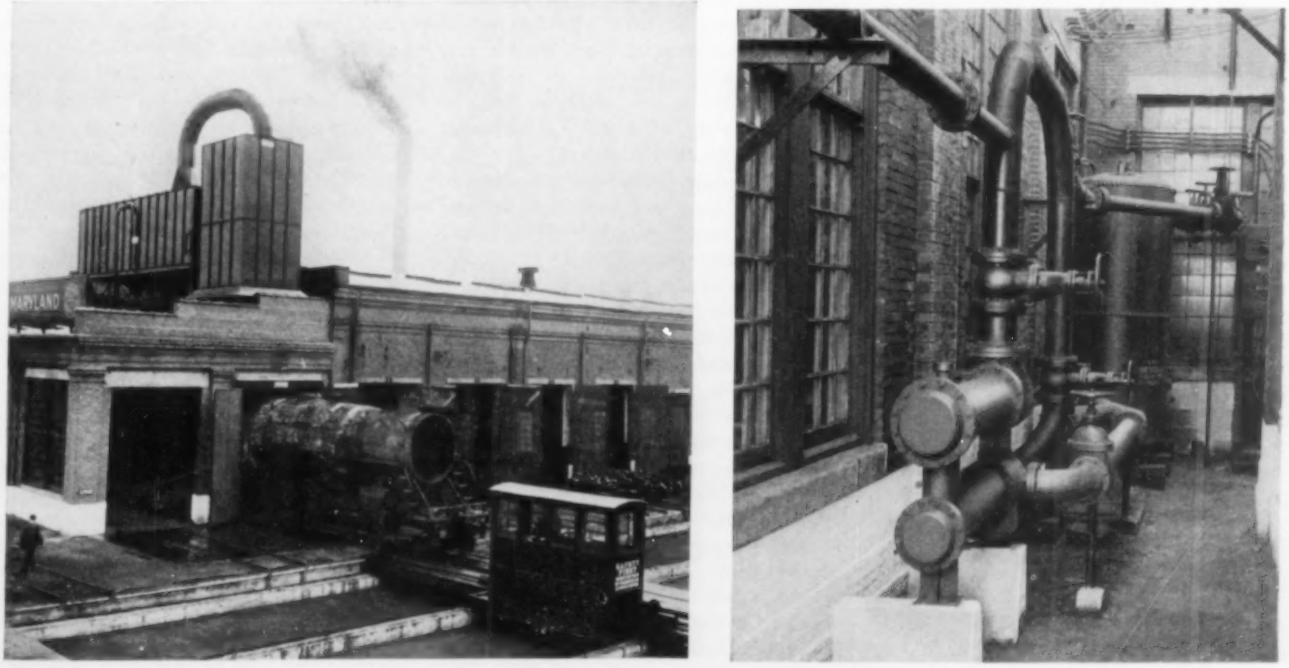
For general work, automatic blasting machines are designed and built in accordance with the product to be cleaned or matte finished. These units include rotating barrels for small pieces in bulk; revolving tables with one or more nozzles oscillating from the hub or center to the rim for flat work; and special machines for the continuous conveyance through the blasting zone of such articles as semifinished heat-treated parts. However, the barrel method is now being used to clean large-sized castings and forgings weighing as much as 300 to 400 pounds. The barrels are rotated for about twenty minutes at 3 rpm., and the abrasive is usually applied with air at 80 pounds pressure.

For large bulky castings of varying kinds and shapes that cannot be handled automatically, there are blast-cleaning rooms housing both the work and the



operator. The airplane industry has chambers of this type big enough to accommodate a fuselage each, a class of work for which sand is generally used. Silicon-carbide and aluminum-oxide abrasives also are suitable for cleaning aluminum, as well as bronze and other nonferrous metals. Gray-iron and steel castings and forgings usually take angular steel grit and steel shot.

The field of application of sand-, grit-, and shot-blasting is too well known and too broad to be covered here at length. But as this article deals primarily with the cleaning of metals, it should be mentioned that blasting equipment has other uses in connection with other materials. To list only a few of the more unusual ones: it is suitable for cutting inscriptions and designs in stone, marble, wood, and glass; for giving glass a frosted finish and wood an antique effect; for graining briar pipes; and for preparing the surfaces of chinaware for glazing.



STRIPPED FOR CLEANING

The picture at the left shows a dismantled locomotive being run into the blasting room at the Hagerstown shops of the Western Maryland Railway Company. To assure the delivery of dry air to the nozzle of the blast gun, this plant is equipped with a 2-pass aftercooler (right) with a built-in moisture separator.

Fire, the Saboteur

AS A PATRIOTIC measure, the National Fire Protection Association and coöperating organizations are making a strong plea for the general observance of Fire Prevention Week, October 3 to 9. Fire, we are told, reduces our war production almost $1,000,000 a day. The aim is to arouse public interest in fire prevention to the point where educational campaigns will be conducted in every community in the nation. Already, members of fire departments in many cities have agreed to make inspection tours of homes, without pay, during their off-duty hours.

For several years past fire has taken approximately 10,000 American lives a year—around 30 a day. The monetary loss during the first six months of this year was $190,514,000. At first glance it would seem that this loss is borne entirely by the property owners, but the truth is that the public at large pays a big part of the bill in the form of higher rentals, higher insurance rates, and higher taxes. When a building burns, it ceases to be a taxpayer. When fire renders people homeless, they sometimes have to be cared for by relief agencies supported by general funds.

Industrial fires are especially deplorable in wartime, for they lessen production and necessitate reconstruction that calls for the use of materials and labor that may be required for turning out vital commodities. Farm fires decrease the food supply at a time when bumper crops are sorely needed. Last year such fires destroyed $80,000,000 worth of property and took 3,500 lives.

The records show that nearly 60 per cent of all fires occur in private dwellings and that these account for half the deaths attributable to fire. The majority of residential fires are traceable to one of the following causes: rubbish accumulations; defective heating apparatus and chimneys; combustible roofs; careless smoking or handling of matches; improper storage of gasoline, kerosene and other inflammables; and faulty electric wiring and appliances. It is contended that virtually all home fires are preventable, and it is urged that every householder make a room-by-room check during Fire Prevention Week to safeguard the premises. Industries are asked to make periodical inspections, to practice "good housekeeping," to organize employees, and to conduct drills often enough for everyone to know just what he should do in case of a fire.

Compressed Air in the War

THE Compressed Air Institute's educational committee has conducted a roundup of compressed air's part in the war effort and has found that it is being used in from 450 to 500 different ways. These applications are extremely diversified, ranging from the mining of ores, the processing of many metals and their fabrication into various machines or instruments of war to the servicing of ships, airplanes, and other equipment entering into actual combat.

Ninety major industries make use of compressed air, and in most of them production would stop if that power were suddenly shut off. In some factories there are as many as 10,000 outlets where the distribution system from a central compressor plant can be tapped to supply power for tools or machines. Enormous quantities of air do useful work every day. In small establishments, the application of air may be confined to operating chucks on a few lathes. All in all, it would be difficult to find any plant engaged in war work that does not depend on compressed air to some extent.

In the building of ships, air power plays an important part in the manufacture of plates, propulsion machinery, and other components. In the assembly of all these, air tools again assume a leading role, and air-operated spray guns paint the hulls before they slide down the ways. When the vessels are in service, air once more is needed, and performs many essential functions such as actuating pressure valves, communication systems, lifts, signal systems, etc. On battleships and cruisers, compressed air scavenges the heavy guns of combustibles after each firing; on submarines, it furnishes the power for starting the diesel engines and helps to send the lethal torpedoes on their way toward enemy targets.

Much of the speed of production now attained in airplane factories is attributable to the diversified services rendered by compressed air. Literally thousands of air-operated tools are utilized in individual plants for drilling, grinding, riveting, and polishing. They are generally lighter per unit of capacity than other types, and manufacturers have developed for the airplane industry small, easy-to-handle tools that have enabled women to take over a large percentage of the jobs and to do them as capably as did the men they released for military service or other work. When the flying machines go aloft, compressed air goes with them. It actuates the mechanism by means of which the wheels are retracted, and when the air pressure is released the wheels come down again for a safe landing. Compressed air also cushions the landing gear against heavy shock when the plane contacts the ground.

Throughout war industries the story is much the same. Even the guns that go aboard ships and those the infantrymen carry could not be built at a rate even approaching the present production speed without the aid of compressed air. Nor could the explosives that fire them be made were it not for the high-pressure compressors that handle constituent gases in essential combining actions. The war effort, concludes the Institute report, has focused attention upon the efficiency of air-driven equipment, particularly because of the need of maximum production with a minimum of manpower.

Where Pain Meant Gain

NO MORE EYESTRAIN

A group of women workers inspecting acorn-sized commutators with the new comparator. The optical instrument consists of two mirrors, four magnifying lenses, and a 6-volt automobile headlight and reflects a greatly enlarged image of the tiny dynamotor part on a glass screen with vertical lines. With this equipment it is easy to determine whether the paper-thin copper and mica strips of the commutator are in perfect alignment, which they must be in order to obtain good aircraft radio reception

HEADACHES and eyestrain were the indirect cause of an invention that has increased production of a vital airplane part by 20 per cent and has, incidentally, cut its cost by 10 per cent. The invention, an optical system applied to an instrument known as a comparator, facilitates the examination of acorn-sized commutators. These little parts are used in dynamotors that supply electric power for aircraft radio equipment.

The thicknesses of the copper and mica strips in a commutator of this size range from 18 to 50 thousandths of an inch. The strips must be in perfect alignment, for a slanted one can create static that interferes with radio reception. Originally, the inspectors at the Westinghouse Electric & Manufacturing Company plant in Mansfield, Ohio, depended upon their eyes alone to detect imperfections. As a result, headaches were frequent. Powerful magnifying glasses provided some relief, but failed to effect a complete solution.

To John R. Weeks, supervisor of the instrument laboratory at the Mansfield plant, is credited the device that finally solved the problem. By means of it, the image of a commutator's surface is reflected on a glass screen after being magnified 22 times, and by comparing the image with vertical lines on the glass screen inspectors can make sure that the paper-thin strips of copper and mica are in perfect alignment. A short time after Mr. Weeks' optical system was put into service, production records showed that 20 per cent more commutators were passing through the inspection lines each day, indicating that the difficulty had been overcome. Moreover, the use of the instrument has made it possible to cut down the number of rejected dynamotors from about 30 per cent to less than 3 per cent. For the ingenuity displayed in developing this production short cut, Mr. Weeks was awarded a $100 war bond by the magazine *Aero Digest*.

New Government Classification for Ore Reserves

AS A MEANS of providing a more comprehensive picture of the nation's mineral resources, the U.S. Bureau of Mines and the Geological Survey have broadened the classification of ore reserves. In describing mineral deposits, the two departments will in future use the terms measured ore, indicated ore, and inferred ore, which are defined as follows:

"Measured ore is ore for which tonnage is computed from dimensions revealed in outcrops, trenches, workings, and drill holes and for which the grade is computed from the results of detailed sampling. The sites for inspection, sampling, and measurements are so closely spaced and the geologic character is defined so well that the size, shape, and mineral content are well established. The computed tonnage and grade are judged to be accurate within limits which are stated, and no such limit is judged to differ from the computed tonnage or grade by more than 20 per cent.

"Indicated ore is ore for which tonnage and grade are computed partly from specific measurements, samples, or production data and partly from projection for a reasonable distance on geologic evidence. The sites available for inspection, measurement, and sampling are too widely or otherwise inappropriately spaced to outline the ore completely or to establish its grade throughout.

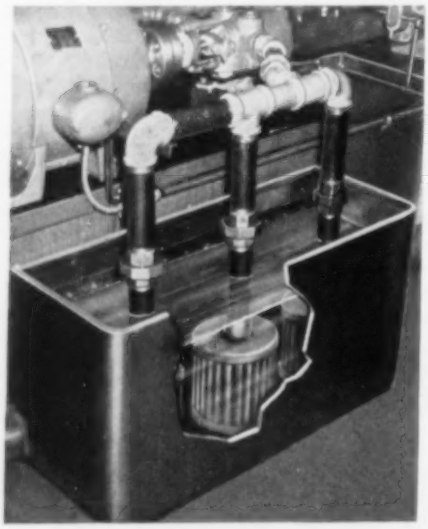
"Inferred ore is ore for which quantitative estimates are based largely on broad knowledge of the geologic character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on an assumed continuity or repetition for which there is geologic evidence; this evidence may include comparison with deposits of similar type. Bodies that are completely concealed may be included if there is specific geologic evidence of their presence. Estimates of inferred ore should include a statement of the special limits within which the inferred ore may lie."

PRODUCTION SHORTCUT

As the result of a worker's suggestion, the time required to wire horizontal stabilizers in the main aircraft plant of the Fisher Body Division of General Motors Corporation has been cut about 17 per cent. This picture shows Russell Dudley demonstrating his improved method, which consists of blowing a piece of string through the conduit with compressed air. The electric wires are then easily pulled through by the cord. Previously, piano wire was used instead of the string, but pushing it through was slow and tedious work on account of the sharp curves in the piping.

Industrial Notes

Staynew Filter Corporation has announced a new sump-type filter that is based on the radial fin construction of the company's air, gas, and liquid filters. The unit is designed for service wherever dirty fluids are collected, filtered, and recirculated, and can be completely submerged in the settling basin or sump upon which the pump draws. The filter medium has a relatively hard finish and is suitable for handling liquids of relatively high viscosity carrying concentrations of metallic cuttings, abrasives, and sludge, as well as mineral oils, both sulphurized and straight, and water-soluble oils that are commonly used as coolants. The material slips over a heavy-mesh form and, like the latter, is characterized by numerous radial fins that provide a maximum of filtering area in a minimum of space and facilitate removal for cleaning or renewal. These, together with an upper end plate with a threaded-sleeve outlet connection, a perforated central supporting tube, and a lower end plate, all held together by a wing nut, constitute the structural parts of the sump filter. It is claimed that installations of this type will protect pumps from abrasive particles that cause rapid wear; will provide clean liquids for reuse; and, by preventing the building up of sand, cuttings, sludge, etc., will obviate the need of frequent inspection and cleaning of hydraulic systems.

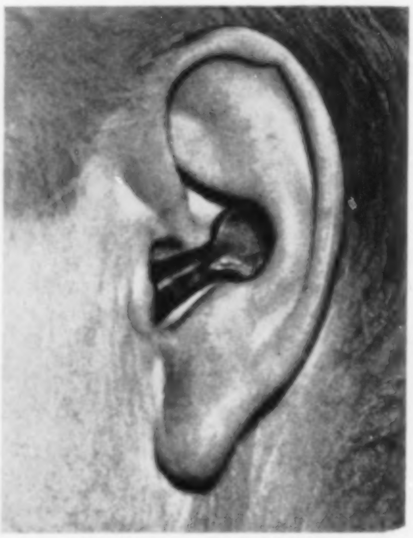


Tall oil or talloel, a fatty, resinous liquid by-product in the making of chemical wood pulp, is the principal ingredient of a hydroemulsive lubricant or cutting oil developed by A. B. Thulinverken, Swedish manufacturer of motor cars and parts, machine tools, etc. It bears the trade name Teveol and has been tested for more than half a year in the company's factories. The coolant is described as a first-class substitute for the mineral-oil emulsions generally used, and machinery so lubricated does not have to be cleaned or supervised oftener than before.

The Magic of Steam is the title of a color-sound motion picture that can be borrowed from Allis-Chalmers Manufacturing Company, Milwaukee, Wis., for one showing or purchased at a cost of $31. Simplified, animated drawings tell how a steam turbine is constructed and operated, show the interior of the turbine chamber from end to end, and illustrate how every part functions. The film is of 16-mm. size and runs for about eighteen minutes.

W. R. Brown Corporation has added a new model—No. 160—to its line of industrial blowguns. The unit has a pistol grip, is controlled by a trigger, and is designed for use with interchangeable nozzles of varying lengths, making it suitable for cleaning surfaces as well as deep holes and recesses. It is built for air pressures up to 250 pounds.

In place of mechanical or magnetic chucking, Leiman Brothers advocate vacuum chucking for holding articles to be ground, beveled, polished, or otherwise finished, and are prepared to furnish equipment for the work. Two chucks have been designed for the purpose, a hollow one with suction connections and a series of countersunk holes and a rotating one of the open or flat, perforated type. It is claimed that the system is suitable for all kinds of materials and well-nigh every line of manufacture necessitating rapid chucking so long as the article to be held has a reasonably flat surface against which the vacuum can exert a pull.



Rohm & Haas Company

SHUTS OUT NOISE

Designed by one of the employees at McClellan Field, this new ear plug is being used there to protect the hearing of workers around engine test blocks and noisy machinery. The plugs are molded from Plexiglas scrapped at the field in the manufacture of **bomber** noses, gun turrets, etc.

For use at expansion joints in concrete construction, the Sonoco Products Company has designed a dowel-bar sleeve with an internal stop pin. The sleeve is made of waterproof paper and

Free!

D Automatic CONTROLS for WATER PUMPS AIR COMPRESSORS and OTHER PUMPING EQUIPMENT

PRESSURE SWITCHES
VACUUM CONTROLLERS
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MAGNETIC UNLOADERS
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AND RELATED DEVICES
AND ACCESSORIES

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A CONVENIENT CONDENSED GUIDE TO THE LATEST IN

PRESSURE SWITCHES

VACUUM CONTROLLERS • FLOAT SWITCHES • MAGNETIC UNLOADERS • LIQUID LEVEL CONTROLS AND RELATED DEVICES AND ACCESSORIES

SWITCH—PROTECT—REGULATE . . . DO IT ALL WITH SQUARE D

SQUARE D COMPANY • REGULATOR DIVISION • DETROIT

slips over the end of the rod. As the concrete expands and contracts with changes in temperature, the sleeve is free to ride on the rod, preventing contact between the latter and the concrete. The product bears the trade name Sonosleeve, is 4¾ inches long, and has an inside diameter of about ¾ inch.

Metal rolls covered with plastic that is impervious to attack by most acids and alkalies are being made by the Rodney Hunt Machine Company. Their surfaces are said to be as smooth as glass and to be highly resistant to wear.

The American-Swedish News Exchange is authority for the report that a professor at the Royal College of Technology in Stockholm has developed a process by which malleable iron can be produced directly from ore in the electric furnace.

Gibraltar Oil Concentrate is the trade name of an inhibitor made by the Hood Refining Company for admixture with lubricating oils. The compound is said to promote their spreading and wetting action, to check the formation of hard carbon, and to prevent lubricants from vaporizing at temperatures higher than those they by themselves can resist.

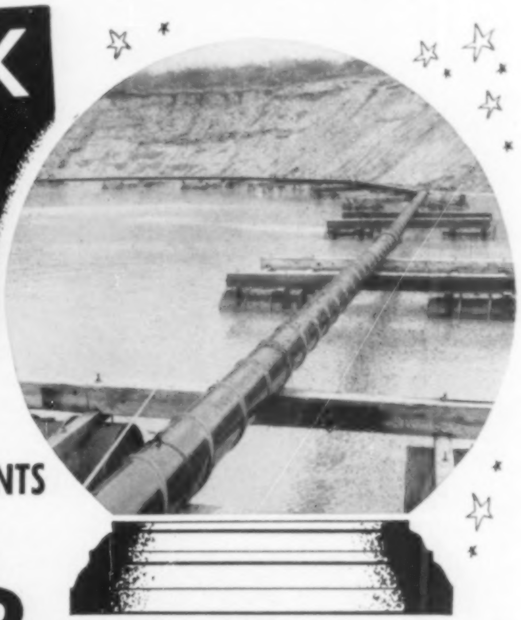
Plastic petroleum—a mixture of oil and wax and an undisclosed ingredient—is keeping our anti-aircraft guns in the naval service in prime condition for their important work of defense. The lubricant protects those weapons against the corrosive action of salt spray and sticks to the metal parts regardless of the high temperatures developed. In the magazines it accounts for the smooth functioning of the guns whether they are operating in frigid Alaskan waters or in the torrid seas of the South Pacific.

Paasche Airbrush Company has announced an improved type of electrically heated air brush for the application primarily in the laboratory of paraffin, waxes, resins, glues, asphalt compounds, heavy oils, greases, vaseline, butter, cheese, molasses, etc. The F974 heats both the compressed air and the material; is fully insulated and thermostatically controlled; is designed to give either a round or a fan spray regulated by a calibrated dial; and is provided with a new type of cup with a snap-on cover to facilitate cleaning and filling. The materials may be applied wet or dry at a temperature ranging from 180 to 320°F. and with air at from 10 to 30 pounds pressure.

By a process of fermentation and distillation, alcohol has been successfully produced from sulphite liquor in a plant built by the Ontario Paper Company of Canada, says *Foreign Commerce Weekly.* Sulphite liquor is a by-product of the paper industry, and it is estimated that the amount now wasted annually in the streams of the United States and Canada would yield a total of 86,000,000 gallons of alcohol. The latter is in great demand today for the manufacture of rubber and explosives and is being obtained by us in part from grain.

Because of its magnitude and the fact that it is expected to relieve somewhat the oil shortage in the East, the construction of the Big Inch pipe line has been followed expectantly by the public. The job is finished, and it is of interest to learn that the Allied Chemical & Die Corporation, which furnished the protective coatings for the steel pipe, has made a permanent record of its progress cross country in the form of a talking movie in color. Requests for the use of the film may be addressed to G. B. McComb, Pipeline Department, The Barrett Division, 40 Rector Street, New York, N. Y.

Under the name of Ridsmel, the Holley Chemical Company is offering a liquid deodorant for paint, varnish, enamel, etc. Claims made for it are that it removes the usual odors that, aside from being objectionable, often are the cause of illness especially in the case of continuous indoor application. One quart of the solution neutralizes 200 gallons without affecting color, drying properties, or durability of the finishes



A PEEK INTO POST-WAR PIPING

TOMORROW'S MINING REQUIREMENTS CALL FOR THESE

NAYLOR ADVANTAGES!

- Always accurate in diameter.
- Concentric ends match correctly.
- Easier to install.
- Holds true cylindrical form.
- Stays tight and leakproof.
- Stronger—safer.
- High salvage value.
- Light weight saves steel.
- Cuts maintenance costs.
- Saves money.

Sizes: 4" to 30" in diameter—all types of fittings, connections and fabrications.

To do your piping jobs better, easier and more economically promises to be a war by-product that will work wonders in the post-war period. The outstanding performance of Naylor light-weight pipe on the battle fronts, plus the research and development work constantly in progress point the way to the solution of many mine-piping problems in the future.

Write for Naylor Catalog

Naylor

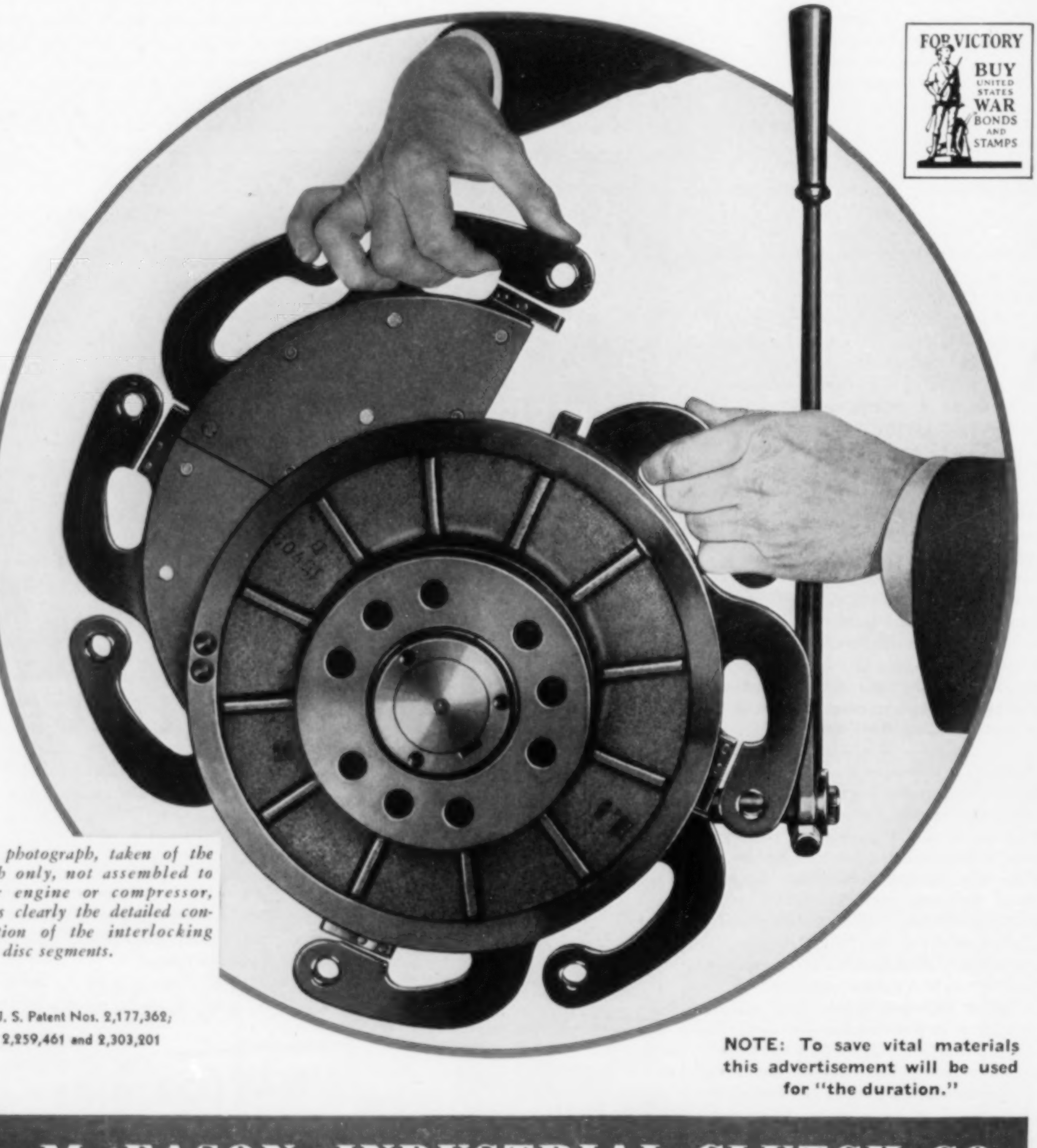
LOCKSEAM SPIRALWELD PIPE

NAYLOR PIPE COMPANY
1245 East 92nd Street
Chicago, Illinois

FLEX-DISC CLUTCHES

Used on the entire line of I-R *Mobil-Air* Compressors, have a time proven drive disc with flexible fingers solidly bolted to the fly wheel. When the friction facings become worn these drive discs, which are quickly detachable in segments, may be removed and relined or replaced without disconnecting the engine from the compressor.

FOR VICTORY
BUY
UNITED STATES
WAR
BONDS
AND
STAMPS



This photograph, taken of the clutch only, not assembled to either engine or compressor, shows clearly the detailed construction of the interlocking drive disc segments.

U. S. Patent Nos. 2,177,362; 2,259,461 and 2,303,201

NOTE: To save vital materials this advertisement will be used for "the duration."

C. M. EASON, INDUSTRIAL CLUTCH CO.

Waukesha Wisconsin

THIS IS THE PACKING OF MANY USES

France Type 414 Packing leads a busy life . . .

Ingenious design has much to do with its usefulness. For example, many 414 cases have plain flanges. Others, frequently found in ammonia compressors, natural gas line compressors, and repressuring compressors, include an auxiliary stuffing box cast with the flange (pictured above).

414 is a rugged brute constructed in heavy, strong sections. The cup sections are pulled snugly together by tie-rods for strength and ease in handling. It is versatile as it can be adapted to various pressures by merely adding the necessary number of cups (from 3 to 10) depending upon the pressure to be held. Oil connections and vent can be taken off at any desirable point and led through the case connecting with the outside of the flange.

Rings are furnished in Carbon-Bakelite for natural gas compressors, in cast iron or bronze for other uses.

Rugged, sectional construction for a wide range of pressures, placement of oil drips and vent to suit conditions, an auxiliary stuffing box when required, and a choice of ring materials, make Type 414 adaptable to a great variety of temperature and pressure conditions—possibly to yours. For further data, please write us.

★ FRANCE PACKINGS and PISTON RINGS ★

FRANCE MFG. CO.

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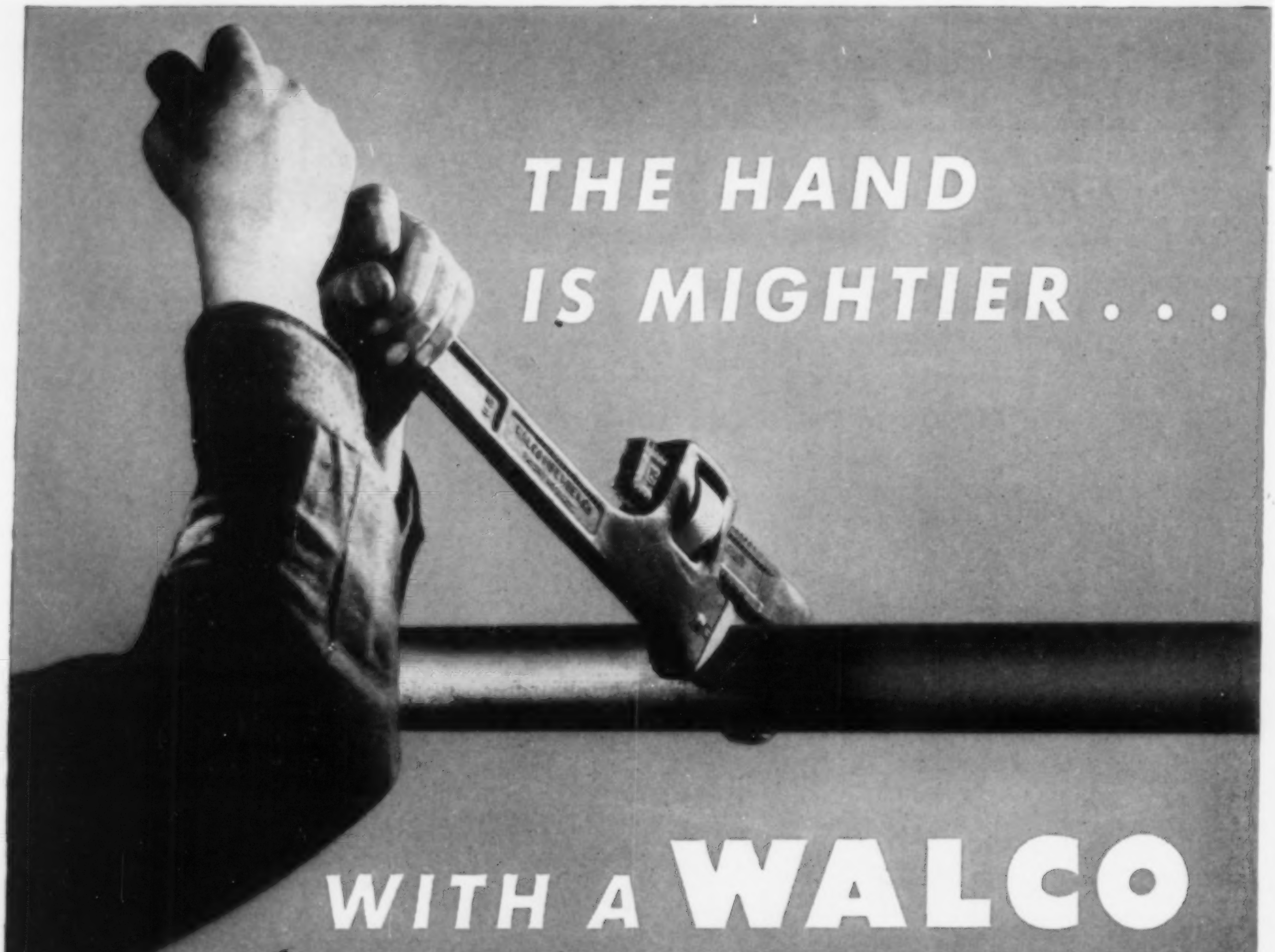
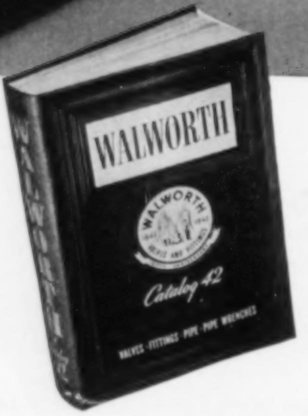
Belgrade and Orthodox Streets, Philadelphia, Pa.





You'll find pertinent information on Walworth's complete line of valves, fittings, pipe, and pipe wrenches in the new Walworth Catalog 42. Included are 78 pages of practical engineering data that simplify valve selection and make piping layouts easier. Write, on business stationery, for your free copy. Address: Walworth Company, 60 East 42nd Street, New York, N. Y., Department 917.

Every part of a Walco wrench is designed and built for strength and safety of operation. The Walco grips and holds no matter how hard you pull. All parts of this modern wrench are **made entirely of steel.** The handle and both jaws are made of drop forged steel. The housing and handle are forged from a single piece of steel. Both jaws are carefully machined, and all parts are heat treated to provide toughness, uniformity, and strength. The cross locked lower insert jaw, which is an exclusive Walco feature, makes it easy to remove a worn lower jaw and insert a new one. The spring may be quickly and easily replaced without the use of tools. These features prolong the life of the wrench indefinitely.

Users everywhere testify to the fact that Walco is the world's strongest wrench, the safest, and by far the least expensive to use. It is made by Walworth Company, manufacturers of valves and fittings for more than a century.

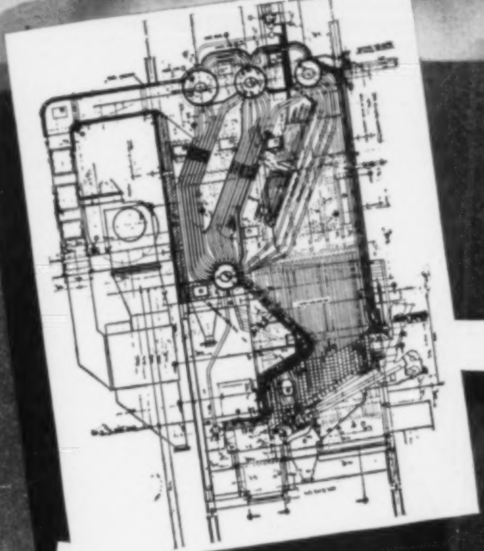
WALWORTH
valves AND fittings

BOSTON WORKS
KEWANEE WORKS

DISTRIBUTORS IN PRINCIPAL CENTERS THROUGHOUT THE WORLD

STEAM

for



POWER

SOUTHERN COLORADO POWER COMPANY
Pueblo, Colo.

90,000 lbs. steam per hour Vogt LE type bent tube boiler with underfeed stoker. Water walls and economizer. Design pressure 525 lbs. Total steam temperature 750 degrees F.

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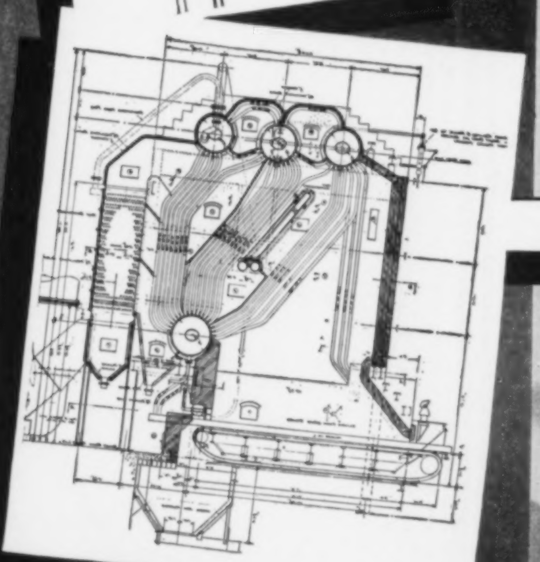

PROCESS

IN A LARGE MID-WESTERN STEEL MILL

Two 105,000 lbs. steam per hour Vogt LE type bent tube boilers with chain grate stokers and economizers. Design pressure 225 lbs. Total steam temperature 550 degrees F.

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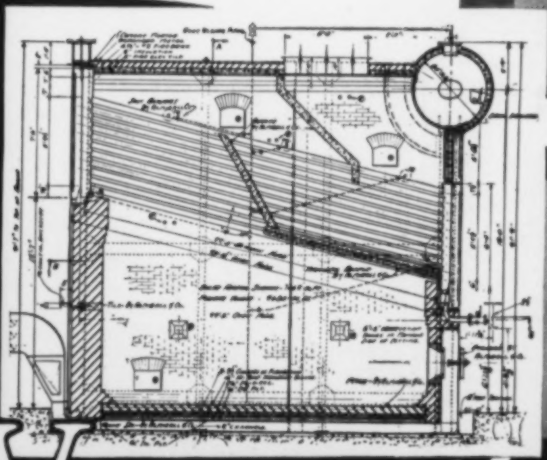


HEATING

CRIMINAL COURTS BUILDING AND JAIL
New York City

Four Vogt sectional header type boilers of 47,000 lbs. steam per hour capacity, oil fired. Design pressure 200 lbs.

Vogt
FOR BETTER BOILERS

HENRY VOGT MACHINE CO.
LOUISVILLE, KENTUCKY
Branch Offices: NEW YORK CLEVELAND
CHICAGO PHILADELPHIA DALLAS

Vogt *Water Tube* BOILERS

BENT TUBE AND SECTIONAL HEADER TYPES

Serving the NATION'S

INGERSOLL-RAND PUMPS FORCE OIL EAST THROUGH THE "BIG-INCH" PIPE LINE

In many of the pumping stations on this 1343 mile line, you will find 1500 horsepower Ingersoll-Rand Cameron Pumps — the largest centrifugal pumps ever used for pipe line service. Thirty-six of these 'lions of the line' are now pushing the oil to where it is needed.

That's only part of the story. The construction of the "Big-Inch" is an epic of American ingenuity and production skill... a masterpiece of organization, engineering, and will-to-win... all made possible by men who know how to roll, weld, wrap, and string pipe. Much of the rock trench work was done with Ingersoll-Rand Air Tools and Portable Compressors.

Ingersoll-Rand compressors, pumps, and engines are serving all divisions of the petroleum industry—refining, aviation gasoline, synthetic rubber, recycling, repressuring, pipe lines, bulk stations, etc.

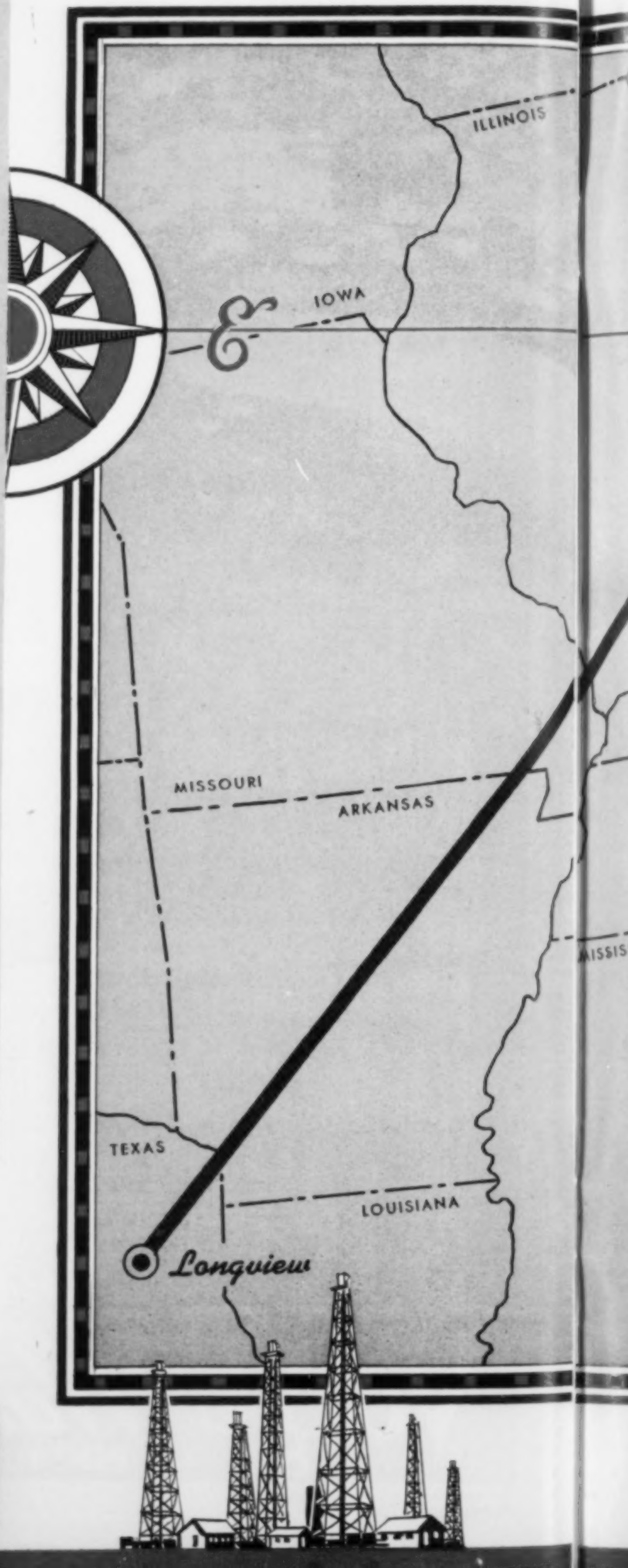
The "Big-Inch" is on stream and soon 41 more Ingersoll-Rand Cameron Pumps will be at work on the new 20-inch Products Line.

All plants of Ingersoll-Rand Company are flying the Army-Navy "E" awarded "for high achievement in the production of war materials."

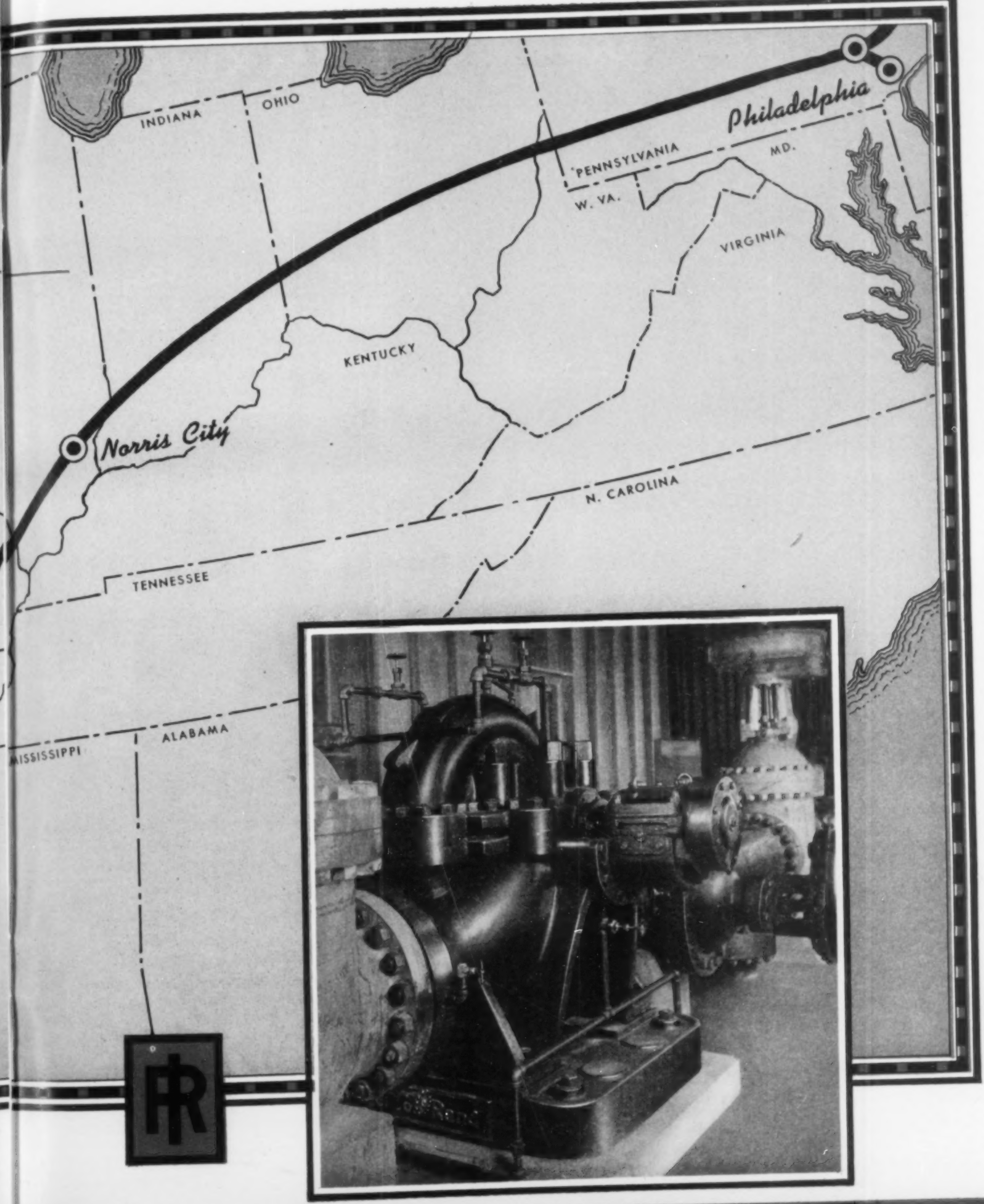
10-358

Ingersoll-Rand

11 BROADWAY, NEW YORK, N.Y.



LIFE LINE ★ ★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COOK'S METALLIC PACKINGS

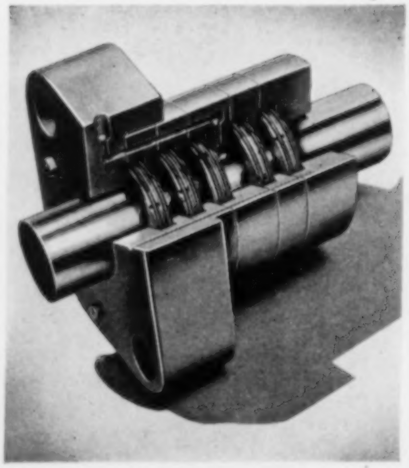
For Piston Rods
of all Engines
and Compressors

Engineered and built to give you more horsepower at less cost

COOK'S precision rod packings come in proved types and materials for all engines and compressors and all prevailing pressures and temperatures—packings that assure you of improved operation with minimum maintenance.

It's a combination of COOK'S basic floating ring design and precision construction which guarantees these results. For this combination assures a positive seal regardless of rod misalignment and vibration and avoids the extra friction and wear these conditions create with ordinary packings.

COOK'S Packings are original equipment in many engines and compressors. They are supplied in others on request. Make sure you get them by specifying COOK'S Packings when you order new equipment. Call or write our nearest Service Office when you want packings for equipment in service—or recommendations as to the correct packing for your particular equipment.



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INCORPORATED
LOUISVILLE, KENTUCKY

SEALING PRESSURES
SINCE 1888

READY! Simplified Catalog of G-E Renewal Parts

GENERAL ELECTRIC
RENEWAL PARTS
AND SUPPLIES

HELPS GET PARTS FASTER

- ✓ Quickly identifies needed parts—pictorially!
- ✓ Simplifies ordering by catalog number
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- ✓ Gives dimensions, descriptions, prices on all parts required most frequently
- ✓ Includes parts for G-E motors, control, switchgear and other widely used electric equipment; also supplies, such as magnet wire, insulating materials
- ✓ Makes it easier to order *genuine* G-E parts, for better fit and long-lasting performance

NOW, a single book—indexed for easy reference—can take the place of separate handbooks and bulletins for identifying and ordering most G-E renewal parts needed to keep your equipment in operation. With this book, you'll find it easier to order genuine G-E parts *by catalog number*—saving time all along the line.

For your copy, just mail the coupon. Even though you don't need it now, it may save precious hours in an emergency. *General Electric Company, Schenectady, N. Y.*

General Electric Co., Section T 750-220
Schenectady, N. Y.

Yes, I want a copy of your new 96-page catalog "Renewal Parts and Supplies (GEA-638)" to help simplify ordering of genuine G-E parts.

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GENERAL ELECTRIC

Air Tools Last Longer

when air lines are equipped with ARIDIFIERS

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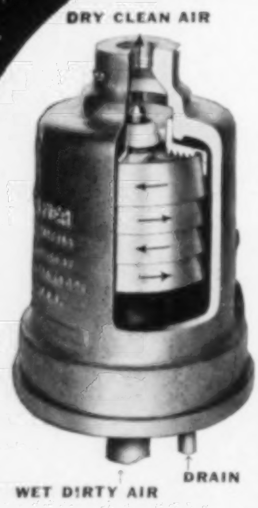
They remove moisture, dirt and fine scale by *centrifugal force*.

Hundreds of plants use from 1 to 452 units.

Send for engineering data.



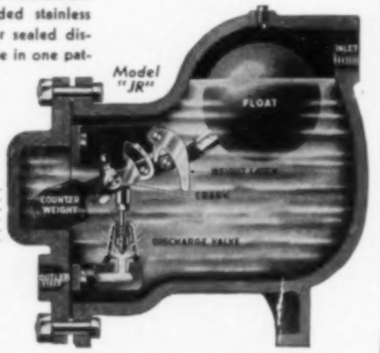
LOGAN ENGINEERING CO.
Makers of Logan Lathes
4911 Lawrence Ave.
CHICAGO, ILL.

The ARIDIFIER
Dries and Cleans Compressed Air

Users Say: "NICHOLSON COMPRESSED AIR TRAPS INCREASE EFFICIENCY OF PNEUMATIC TOOLS BY PROPERLY DRAINING AIR TANKS, RECEIVERS, AFTER COOLERS, ETC."

The Nicholson "JR" Trap is specially designed and constructed to provide long, trouble-free service under continuous operation. Large capacity . . . for pressures up to 200 lbs. . . . intermittent discharge . . . welded stainless steel float . . . water sealed discharge valve . . . made in one pattern size only with either ½", ¾" or 1" inlet and ½" outlet.

Write NOW for Bulletin No. 341



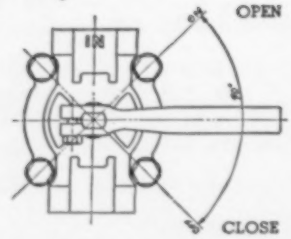
W. H. NICHOLSON & CO., 180 OREGON ST., WILKES-BARRE, PA.

NICHOLSON *Traps*
THERMOSTATIC ▼ PISTON AND WEIGHT-OPERATED STEAM
GASOLINE AND COMPRESSED AIR TRAPS
CONTROL VALVES ▼ FLOATS ▼ MANDRELS ▼ STEAM AND AIR SEPARATORS

Save AIR, TIME, EFFORT!

with **NOPAK** Quick-Opening SHUT-OFF VALVES

Finger-Touch



Quarter-Turn Lever Control
A quarter-turn of the valve lever positively opens or closes the valve, permits quick or throttling action. Position of lever shows degree of opening.

A flick of the finger opens or closes the NOPAK Shut-Off Valve. There's no slow, laborious wheel-turning . . . no pressure lost while valve is manipulated . . . no working time lost!

On lines connected to air guns, chipping hammers, drills and other air powered tools, these quick-acting valves prevent air waste, conserve valuable man hours for production effort.

The patented NOPAK Rotating Disc principle makes these shut-off valves leakproof and wearproof. Their flat, lapped-disc sealing surfaces improve with use. There are no tapered plugs or interlocking contours to stick or wear out . . . no packing to replace. Pressure sealed disc and seat are always protected from grit abrasion. May also be used for Oil, Water or Gas.

Write for Illustrated Folder

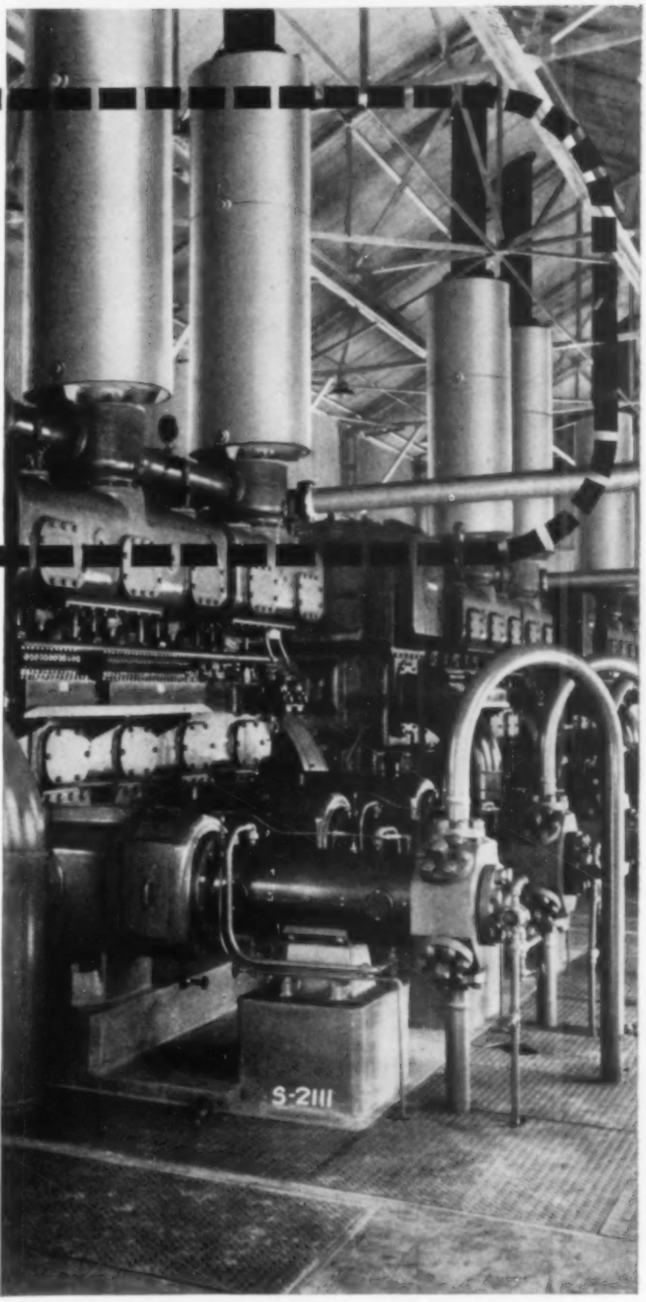
GALLAND-HENNING MFG. CO., 2759 S. 31st St., Milwaukee 7, Wis.

Representatives in Principal Cities

NOPAK VALVES and CYLINDERS
DESIGNED for AIR or HYDRAULIC SERVICE

A 4104-½H-A

so that men can hear themselves think . . .



In providing effective silencing for Diesel exhaust, Maxim Silencers contribute largely to the efficiency of the man-hours within a plant. Excessive noise acts as a specific strain on nervous systems, but beyond this, in a noisy plant, routine and necessary instructions may be incorrectly heard or not heard at all. Then, of course, there are always those living near the plant, war workers trying to sleep during the day, near neighbors carrying on their daily routine . . . all of whom benefit when Maxim Silencers do their job day and night.

MAXIM WASTE HEAT UNITS SAVES FUEL

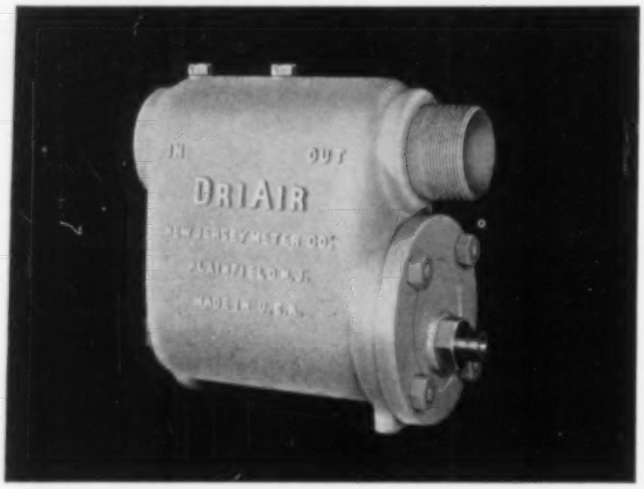
Maxim Waste Heat Units utilize waste exhaust heat to produce steam or hot water for use in heating or processing operations. These units are compact and efficient and combine waste heat recovery with effective silencing of exhaust noise and, where indicated, with the positive Maxim Spark Arrestor feature.

EXHAUST and INTAKE
SILENCERS

Widely used today in the marine field where fuel saving is of prime importance, Maxim Waste Heat Units are also finding broad applications in the industrial field. Descriptive Bulletins WH-100, WH-102, WH-103 on request. The Maxim Silencer Co., 85 Homestead Ave., Hartford, Conn.

MAXIM

DEPENDABLE PNEUMATIC SERVICE

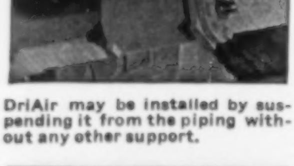


WHEN EQUIPMENT IS PROTECTED BY

DRIAIR

A COMPLETE SELF-CONTAINED UNIT

DriAir may be installed by suspending it from the piping without any other support.



A typical installation showing DriAir standing on the floor next to the wall.

● The answer to many problems which arise in various applications of compressed air, DriAir speeds production by separating and automatically ejecting the condensed water and oil from the air. DriAir collects dirt and rust from the air lines and delivers clean dry air to the tools, thus reducing wear and prolonging their life. All internal parts are made of bronze or copper—resistant to corrosion and practically permanent. Copy of Bulletin DA fully describing the operation of DriAir sent on request; write today.

NEW JERSEY METER COMPANY
PLAINFIELD, NEW JERSEY

THE *Safe* WAY TO POUR Babbitt!

Use Babbitrite, the proven, time-tested babbitt retainer instead of make-shift materials. Eliminate costly time-consuming blow-outs, the danger of injury from hot molten metal. Babbitrite is moisture-proof, is not affected by heat and will not harden. Comes ready-for-use, requires no mixing and can be used over 100 times.

Write for liberal sample.

Babbitrite
AS NECESSARY AS THE LADLE

BABBITT RETAINER
●
PRODUCTS MFG. CO.
517 E. Buffalo St. • MILWAUKEE 2, WIS.

A 4144-¼

Remember
IT'S EASILY APPLIED
NO VISE NEEDED
ONLY ONE WRENCH

60 YEARS *of Safety* 1883 - 1943 *the Genuine* CROSBY CLIP

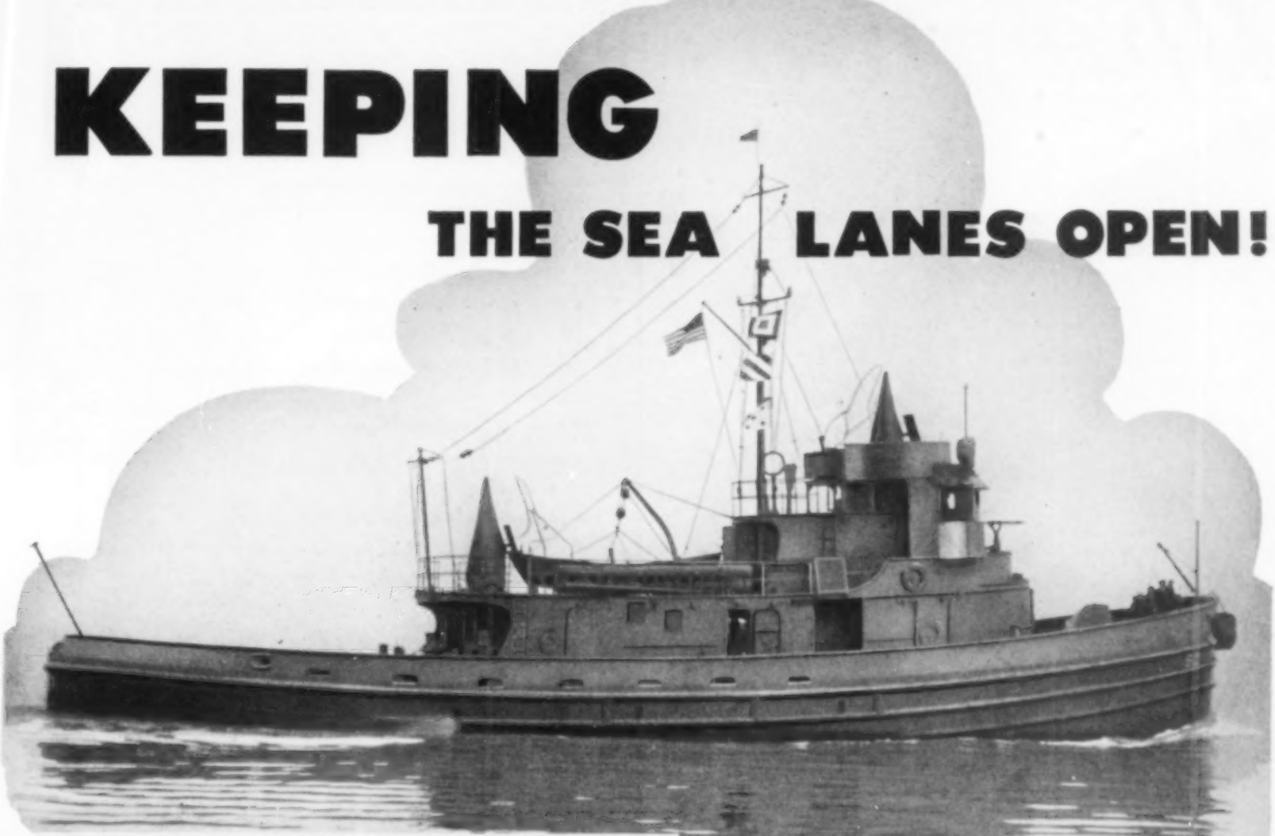
AMERICAN HOIST AND DERRICK CO.
SAINT PAUL 1, MINN.
Chicago · San Francisco · New York

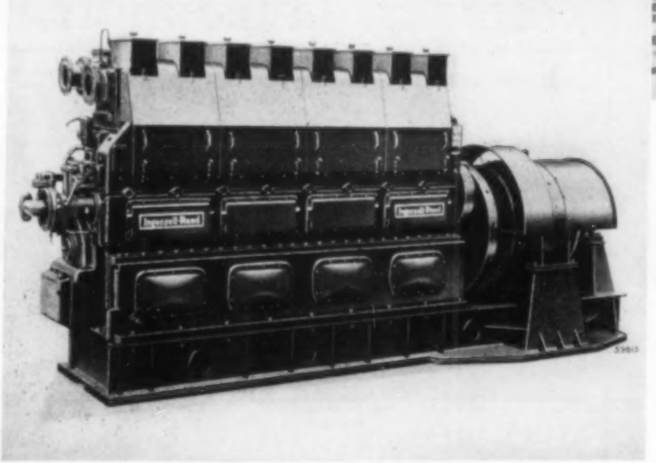
AMERICAN TERRY DERRICK CO., South Kearny, N. J.

You know Genuine **CROSBY CLIPS WILL HOLD SAFELY** *Because they have been doing it for 60 years*

Developed in 1883 and improved with every technological advance, the *Genuine* **CROSBY CLIPS** more than kept pace with all improvements in wire rope construction.

KEEPING THE SEA LANES OPEN!





Complete Type "S" Diesel Engine generator sets are available in sizes from 150 to 400 kw. They are direct-connected with a rigid coupling, and are mounted on a strong but lightweight fabricated steel sub-base.

Many of the Diesel-electric-driven ships in the United States Coast Guard's new fleet of ice breakers are powered with Ingersoll-Rand Type "S" Diesels.

The several unusual design features embodied in these power plants cannot be mentioned at this time. Significant, however, is the Coast Guard's choice of dependable 4-cycle power for ships in the vital service of keeping the sea lanes clear, even to the remotest American outpost.

More power to the fleet that clears the way for United Nations' shipping!

Ingersoll-Rand

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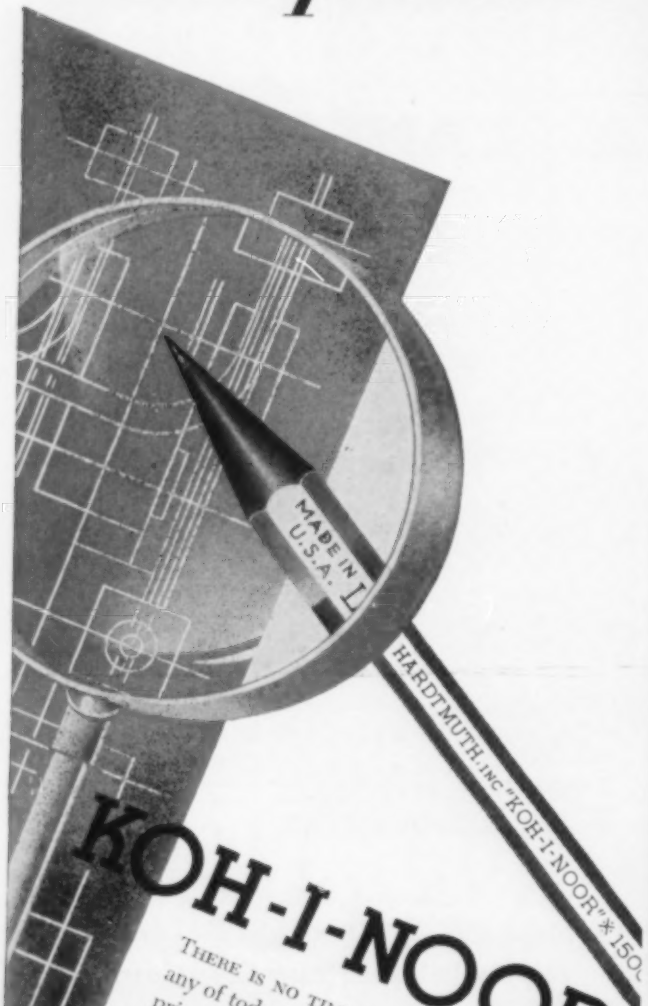
CENTRIFUGAL PUMPS • CONDENSERS • COMPRESSORS • TURBO BLOWERS • ROCK DRILLS • AIR TOOLS • OIL AND GAS ENGINES

Blueprints



KOH-I-NOOR

THERE IS NO TIME TO SPARE in producing any of today's requirements. Readable blueprints must be rushed to production departments without delay and the fabrication of parts started.

For any important task, KOH-I-NOOR DRAWING PENCILS have long been the unanimous choice of discriminating draftsmen. You will most certainly approve their smooth, long wearing qualities and their ability to produce well defined, light impervious lines, resulting in clearer, more legible blueprints.

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DON'T WASTE
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Here's help . . .

FOR YOUR COMPRESSORS

NUGENT Flared Tube Union Fittings can help you keep your compressor equipment operating FULL TIME with maximum efficiency. These fittings withstand vibrations at high pressure without pressure leakage. The flared tube makes its joint on the end of the fittings hence, the tubing must only be sprung over the seat on the end of the fitting, which is 3/32" on small sizes and 1/4" on larger sizes. Made in all styles shown in sizes 1/8" to 3/4" OD pipe sizes.

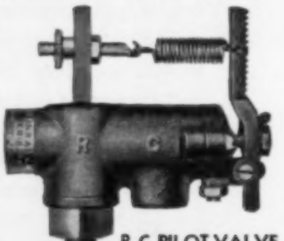
NUGENT TRADE MARK

Wm. W. NUGENT & CO., INC.
422 N. Hermitage Ave.,
Chicago 22, Ill.
Est. 1897

NUGENT
COMPRESSOR EQUIPMENT

R. C. PILOT VALVES FOR POSITIVE CONTROL

R-C Unloader Pilot Valves (plain or strainer type) are standard on many leading compressors . . . installed as replacements on thousands of compressors in all parts of the U. S. A. and overseas. The R-C valve—positive in action—cannot chatter . . . it's always in open or closed position. Adjustment is provided for any unload-to-load range from 3% to 30% of maximum receiver pressure. Install an R-C Unloader Pilot valve—let performance prove its value. Specify air pressure and range of on-and-off operation desired. Write for price and recommendation.

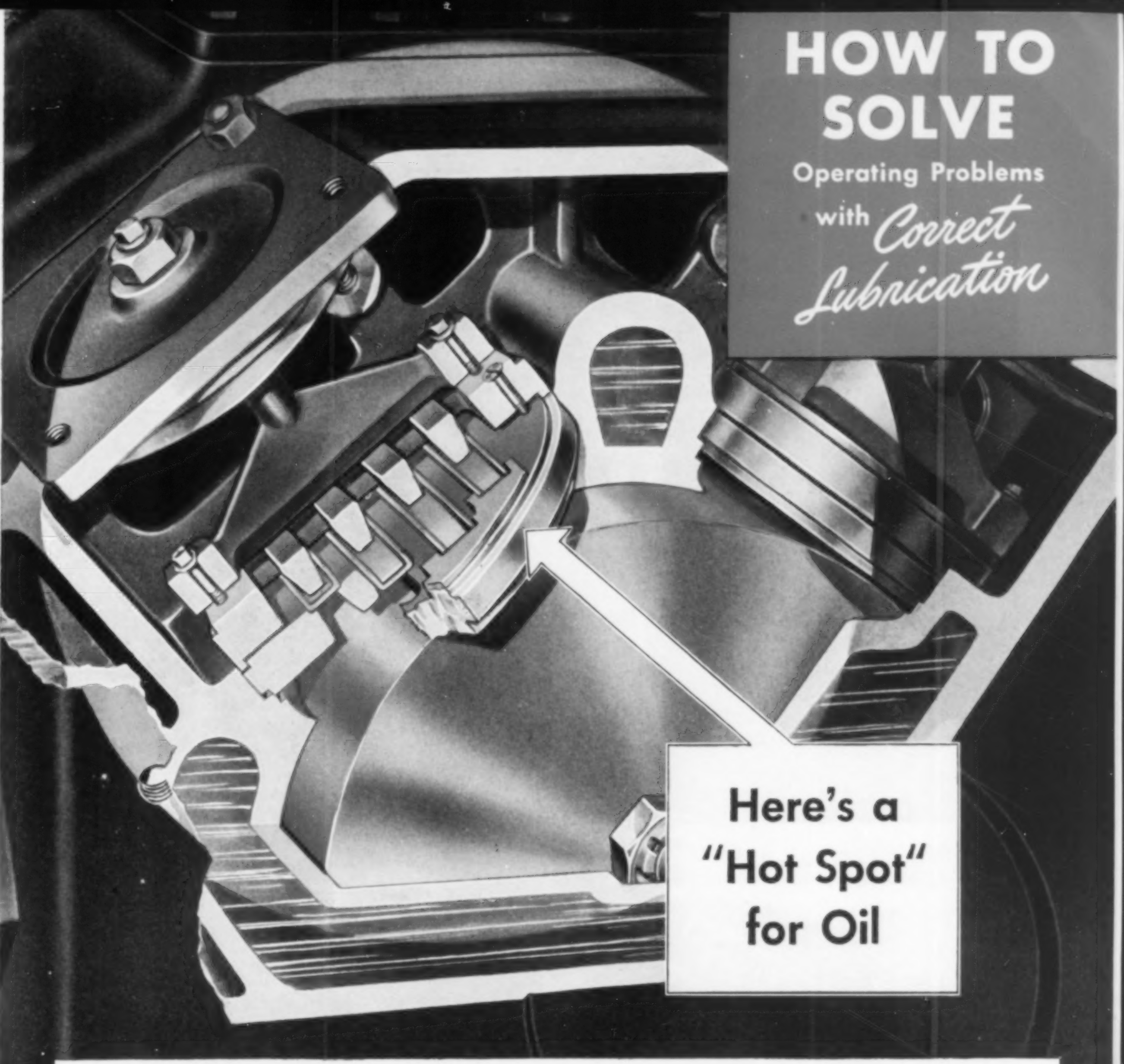


R. C. PILOT VALVE
STRAINER TYPE

R. CONRADER CO.
1207 FRENCH STREET - ERIE, PA.
PILOT VALVES for Portable and Stationary Air Compressors provided with Unloaders

ONE OF A SERIES OF SUGGESTIONS TO AID PRODUCTION

HOW TO SOLVE
Operating Problems with *Correct Lubrication*


Here's a "Hot Spot" for Oil

Those Valves Must Stay CLEAN!

HERE'S WHAT dirty discharge valves can result in: *Leakage of air, decreased capacity, lower efficiency, higher discharge temperature.*

For assurance of clean valves—use the correct oil.

The oil—carried past the valve by the compressed air—coats it with a necessary oil film. The oil must not oxidize on this "hot spot." That is why it must provide:

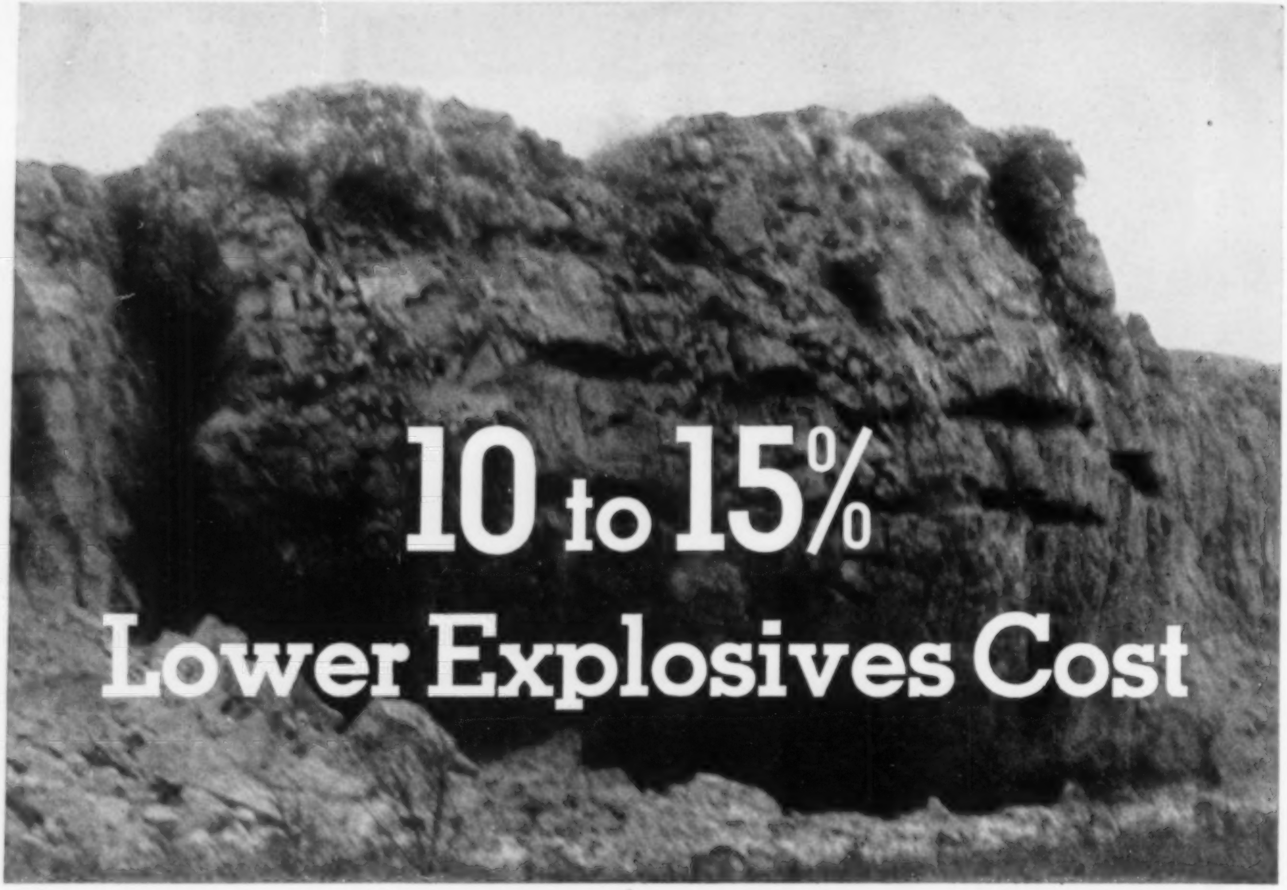
1. High chemical stability—freedom from deposit.
2. High lubricity—full protection to piston and cylinder with minimum feeds. This minimizes the amount carried to the discharge valves, further safeguarding against deposits.

You'll find Gargoyle D. T. E. Oil does *both* jobs well. It will help you secure full capacity output with minimum time and expense needed for maintenance or repairs.

SOCONY-VACUUM OIL CO., INC.—Standard Oil of N. Y. Div. • White Star Div. • Lubrite Div. • Chicago Div. White Eagle Div. • Wadhams Div. • Magnolia Petroleum Co. • General Petroleum Corporation of Calif.

GARGOYLE
Lubricants

CALL IN SOCONY-VACUUM



10 to 15% Lower Explosives Cost

HERCOMITE 4
DANGER

HERCOMITES*

The high weight strength and high cartridge count of the Hercomite explosives make them unusually economical. In comparison with the more conventional materials of this class, the Hercomites offer a 10% to 15% reduction in explosives costs. Hercomites are available in six different grades. They are especially suited for quarry work and for many underground operations.

GELAMITE 2
DANGER

GELAMITES*

The water resistance and plasticity of Hercules Gelamites permit their use under many water conditions which formerly demanded the more expensive gelatin explosives. Savings of 10% to 15% are realized when Gelamite 1 replaces 60% gelatin extra and Gelamite 2 replaces 40% and 50% gelatin extra. Like the Hercomites, they are especially suited for quarry work and for many underground operations.

*Reg. U. S. Pat. Off. by Hercules Powder Company

A-98

HERCULES EXPLOSIVES

932 KING STREET, WILMINGTON, DELAWARE

Increase

HIS ABILITY

Give Him

AIR TOOLS

Every worker has the desire to produce. Give him the proper tools and he'll do it.

Any portable power tool will increase the output of the operator's hands, but a lighter, smaller AIR tool of comparable power will *further* increase his production.

Ingersoll-Rand AIR tools are wanted by men on production lines. Here's why . . . . . .

LIGHT WEIGHT AIR tools are *lighter in weight* than other types of portable power tools, and are about *one-half the size.* This is an important factor in reducing operator fatigue.

FLEXIBILITY AIR tools give maximum power *immediately.* Starting and stopping are practically instantaneous. This speeds up repetitive operations. *Regulation of power* permits the use of the tools on many kinds of materials and on many types of operations.

DURABILITY *Trouble-free service* is assured by the sturdy construction of AIR tools. AIR motors cannot be damaged by overloading.

POWER *Air tools have more power per pound,* thereby enabling the operator to produce more work with less effort.

SAFETY *Air tools are safe* because they are easy to handle and are simple in design. Compressed air is the safest medium for the transmission of power for portable tools.

Give the man on your production line every possible help! . . . GIVE HIM AIR TOOLS!

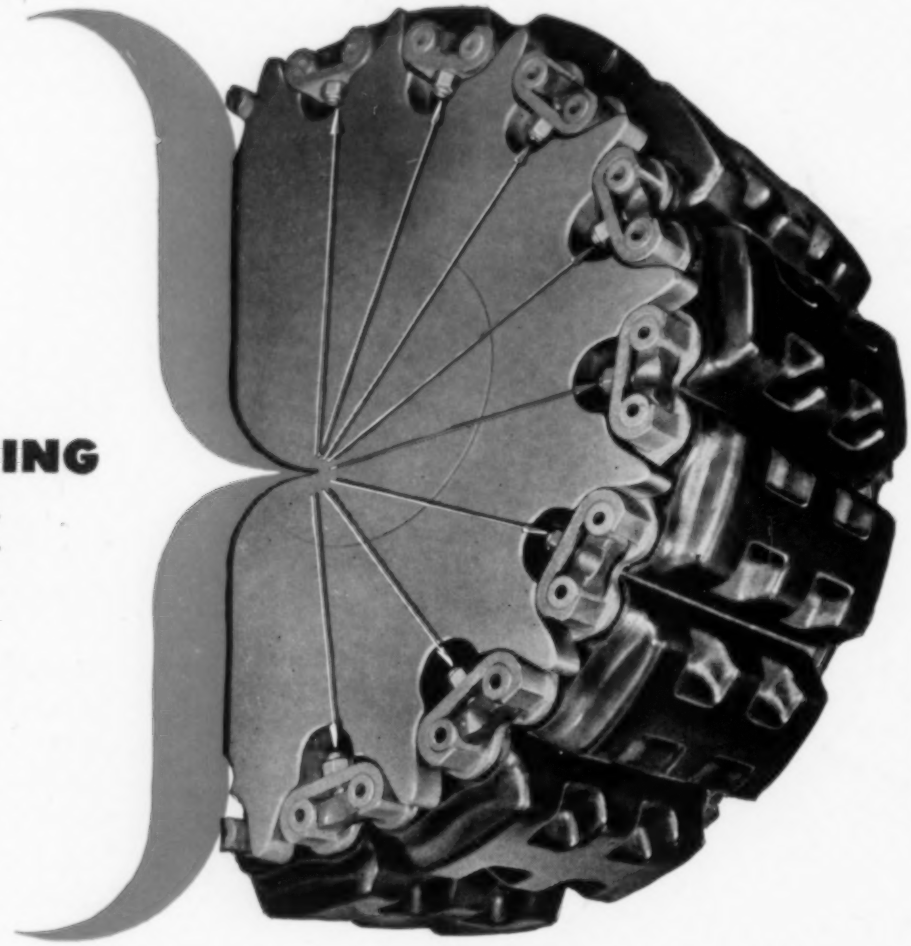
Ingersoll-Rand

11 BROADWAY, NEW YORK 4, N. Y.

8-350

COMPRESSORS • TURBO BLOWERS • ROCK DRILLS • AIR TOOLS • CONDENSERS • DIESEL ENGINES • CENTRIFUGAL PUMPS

HARNESSING THE KICK OF 1000 HORSES



- Here's the drive cog of a tank.

It tugs that tread with a yank that has as much as a thousand horsepower back of it.

And Elastic Stop Nuts—a single one on each lug—hold that tread.

This is just one of the war-fastening jobs Elastic Stop Nuts are doing. There are more of them on America's planes, tanks, guns, naval vessels and production equipment than all other lock nuts combined.

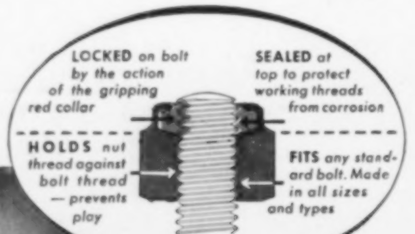
You know why.

It's because of the red elastic collar which makes these nuts lock fast and stay put in the face of vibration—anywhere on the bolt.

This collar molds itself tightly to the bolt. It keeps the nut and bolt threads in pressure contact. The nut can't wiggle or turn.

Later on, these nuts will be available to do this kind of job for industry. Products will be better, stronger, longer-lasting. Production routine will be free of frequent "take-ups," inspections and replacements.

If your postwar planning includes a fastening problem, let us know. Our engineers will gladly suggest a way to solve it and recommend the appropriate Elastic Stop Nut.


LOCKED on bolt by the action of the gripping red collar
SEALED at top to protect working threads from corrosion
HOLDS nut thread against bolt thread — prevents play
FITS any standard bolt. Made in all sizes and types

ELASTIC STOP NUTS

Lock fast to make things last

ESNA
TRADE MARK

Elastic Stop Nut Corporation of America
UNION, NEW JERSEY AND LINCOLN, NEBRASKA